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BREEDING AND QUALITY EVALUATION OF IMPROVED ALTERNATIVE WHEATS

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"BREEDING AND QUALITY EVALUATION OF IMPROVED ALTERNATIVE WHEATS"

Final Report

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ABSTRACT

A new spring spelt candidate variety which is awnless, higher yielding, stronger strawed, earlier maturing and higher in grain protein content than the currently registered variety was developed. The use of emmer wheat to introduce bread wheat equivalent baking quality to durum wheat, yet produce acceptable pasta was demonstrated. Einkorn lines with bread-making potential and higher levels of lutein were identified. Large-seeded lines from crosses between durum and Khorasan and Polish wheat were developed. Selection for the rice-shaped kernel resulted in a non-arched kernel which should reduce grain-cracking during the puffing process.

INTRODUCTION

Background information

Hulled wheat species such as spelt (Abdel-aal and Hucl 2005), einkorn and emmer offer new market opportunities.

The objectives of this project were to evaluate improved spring spelt, einkorn, puffing, and baking-quality durum/emmer wheat derivatives. Alternative wheats are required to undergo formal testing for cultivar registration purposes. A Private Spring Spelt Wheat Cooperative Wheat Test was initiated by the CDC in 2001 with the objective of bringing an awnless, agronomically improved cultivar to registration. We have developed improved einkorn wheats for cake and cookie production. However, a recent study has shown that certain einkorn wheats are high in the pigment lutein. Lutein is thought to be associated with reduced macular degeneration in the elderly. As part of this project we proposed to evaluate a collection of einkorn accessions as well as our breeding lines for lutein. The objective was to identify high-lutein lines that can be used as parents in crosses with agronomically desirable einkorn wheat parents. Likewise, we proposed to increase the lutein level in bread by the development of durum/emmer wheat derivatives. The expected results were the delivery of agronomically superior alternative wheats that would lend themselves to organic and other specialty markets. Improved agronomic performance will improve the economics of growing alternative wheats such as spring spelt.

The spring spelt variety CDC Bavaria (SK0263) received interim registration from 1996 to 2001. In early 2001 the CDC sought support for full registration from the Prairie Registration Recommending Committee on Grain (PRRCG). This support was provided and Registration was granted by the CFIA in November, 2002. Since the name 'Bavaria' was being used by a USA soft white winter wheat cultivar, we were required to change the name of SK0263 from CDC Bavaria to **'CDC Nexon'**. CDC Nexon is the first registered spring spelt wheat cultivar in North America, and in the OECD sphere. Small amounts of seed were made available directly from the CDC, starting in 2003.

Virtually all spring spelt accessions we have screened are awned. This is the case for CDC Nexon. The awns tend to aggravate the lodging susceptibility of spelt wheat and reduce the density (bushel weight) and handling properties of the crop. Winter spelt wheat is awnless. Hence it was hypothesized that using the awnless trait would benefit spring spelt. In addition this would be accomplished by using true spelt x true spelt crosses and not using spelt x common wheat crosses, thus addressing current market requirements for non-introgression with post-Industrial Revolution wheat.

As part of an earlier ADF project (97000262-95BR) we developed a series of awnless spring spelt wheat lines from spring x winter spelt crosses. This material was tested in-house at the CDC in 1999 and 2000 in replicated trials. A dozen lines were selected for wider adaptation trials in 2001. The CFIA via the PRRCG has instituted a formal variety registration requirement for Spelt wheat. This necessitated the creation of a Cooperative test. The Private Spring Spelt Wheat Cooperative Test (PSSWCT) as proposed by the CDC (P. Hucl) was sanctioned by the PRRCG

for agronomic, disease and quality evaluation in February 2001. The test is run in much the same manner as a bread or durum wheat Registration Test.

Specific einkorn wheat accessions contain elevated xanthophyll pigment levels. Specifically einkorn contains the yellow pigment lutein in concentrations 4 to 5 times higher than common wheat and ca. 20% higher than in durum wheat (Abdel-Aal et al., 2002). Elevated lutein levels are thought to be associated with lower a lower incidence of age-related macular degeneration (AMD). AMD is the leading cause of blindness in the elderly.

We proposed to screen in excess of 200 einkorn accessions for yellow pigment levels. In addition, we proposed to test all our most advanced breeding lines. Until the initiation of this project, pigment content had not been a selection criterion in our breeding efforts.

In order to take advantage of the potential health benefits of lutein, we have been developing baking quality tetraploid wheats. Traditional durums have poorer baking quality than common wheat, although Extra-strong durums do lend themselves better to bread-making (Marchylo et al., 2001). We initially developed a series of experimental lines by crossing a semi-dwarf ES durum with an emmer accession characterized by baking quality equal to CWRS wheat. The lines were selected for strong gluten properties, high loaf volume and pigment content as well as threshability. The first cycle of lines are 20% lower-yielding than standard durum cultivars, largely due to poor leaf disease reaction. In order to rectify this problem we used the highest-quality first cycle line and crossed it to a number of durum cultivars.

Our most advanced puffing wheat lines evaluated up until 2001 were lower-yielding and lower in test weight than desired. We developed populations to address those short-comings.

METHODS AND RESULTS

METHODS

SPRING SPELT PRIVATE REGISTRATION TEST 2002-2006

In 2002 and 2003 the Spring Spelt Registration Test was grown at 7 sites. The volunteer Cooperators were Drs. A. Brule-Babel (University of Manitoba-Winnipeg), R. Depauw (AAFC-Swift Current), D. Salmon (AFCDC-Lacombe) D. Spaner (University of Alberta – Edmonton) and Mr. S. Dueck (AAFC- Scott, SK). Disease data was collected by the University of Saskatchewan. Yield data from Winnipeg in 2002 was not included due to a high CV. The site at Scott in 2003was lost due to severe sawfly injury.

In 2004, 2005 and 2006 the spring spelt "Coop" was grown at 8 sites. Dr. D. Spaner (University of Alberta – Edmonton) provided the eighth site. Fusarium Head Blight data was collected by the University of Manitoba at Carman MB.

The test objectives and protocols were as follows: to evaluate spring spelt wheat lines for Cultivar Registration purposes following PRRCG-sanctioned protocols for the Western Bread Wheat Coop

Test. Agronomic and disease performance were assessed. Quality evaluations were performed by the Crop Development Centre Grain Quality Testing Laboratory.

Field Trials: A minimum of 12 trials (station-years) over three years were established, with a minimum of one per prairie province per year. Up to five of the trials were conducted by independent cooperators (minimum four independent cooperators).

A three-rep Randomized Complete Block Design was used for testing 10-12 wheat lines per year. The cultivars AC Barrie (CWRS) and CDC Nexon (Spring spelt) wwere used as checks. The spelt grain was dehulled for planting purposes. The seeding rate was the same as that used for CWRS wheat. The seed was untreated. Weed control was as per non-spelt spring wheat Coop Tests.

With the exception of sawfly reaction, data collection followed the guidelines set for the Western Bread Wheat Cooperative Test **(PRRCG 2000 Minutes: Appendix C, pg 17).** The traits to be measured included: Grain yield, Days to maturity, Plant height, Lodging, Test weight (by Coordinator), Kernel weight (by Coordinator).

Quality Evaluation: KVD (by the CGC), grain protein, milling yield, ash content, flour protein, Farinograph properties, baking quality (Canada Short Process) were assessed in the CDC quality lab (by C. Perrron)

Disease Evaluation: The disease reactions to be assessed included: Stem and leaf rust, common bunt, loose smut and fusarium head blight (FHB).

A written report was presented to the PRRCG-WRT subcommittee at the Annual Meetings. The report format followed that used for the Western Bread Wheat B Test format and included end-use quality data.

OTHER YIELD TESTS (2002 TO 2006)

Yield testing for this project was conducted using 2 replicate RCBD trials. Typically, each test was conducted at 2-4 sites each year. The sites included the University of Saskatchewan Seed Farm (early versus late-seeding dates), Kernen Crop Research Farm and the Goodale Research Farm. Individual plots consisted of five rows 3.6-m long. Rows were spaced 0.2 m apart. Plots were sown at a rate of 250 seeds m^{-2}. Fertilizer was drilled in with the seed at recommended rates to supply sufficient levels of N-P-K. Weeds were controlled using herbicides and, when necessary, hand-hoeing. Plots were combine-harvested at maturity and grain samples were dried using forced air driers. Data were collected for days to heading (50% spike emergence = **DSE**), days to maturity (95% physiological maturity = **DPM**), plant height, lodging, test weight **(Twt)**, kernel weight **(Kwt)**, leaf blight **(LBL)** and grain yield. For Khorasan-type wheat trials, 20 seed length **(20SL)** was calculated on a random grain sample. Statistical analyses were conducted using Agrobase or Minitab (V13). Unreplicated yield trials consisted of 31 experimental lines (standard plot size) with five plots of the check variety equally distributed across the test. The unreplicated tests were handled in the same manner as the replicated tests in terms of data collection. For replicated trials, only those with Coefficients of Variance (CV) of less than 15% for grain yield were retained for presentation, unless the genotypic effect was significant at

P=0.05 or better. For example the CV's for the Spring Spelt Registration Test averaged 11.6%, 7.3%, 10.2 and 7.9% in 202, 2003, 2004 and 2005, respectively. For the pre-Registration evaluation of spring spelt experimental lines the average CV's were 3.6% (2003), 6.0% (2004) and 7.1% (2005). For the emmer-durum derivatives (Tables 17 and 18) the average CV's were 15.5% (2002) and 6.2% (2003). For the evaluation of einkorn lines the average CV's were 10.4% (2002), 8.1% (2003 Table 22a), 7.7% (2003 Table 22b), 7.0% (2004) and 8.4% (2005). For the Khorasan-type germplasm the average CV's were 16.0% (2002), 6.0% (2003), 7.8% (2004) and 6.8% (2005). The CV's were marginal in 2002 due to the extreme drought conditions. This was especially the case for the emmer-durum and Khorasan-type germplasm.

For quality evaluations AACC methodology was followed. The majority of quality analyses were conducted on a grain composite over replications and sites within years and were not amenable to statistical analysis.

RESULTS

The 2002 crop season was the poorest on record for the Saskatoon region. No rainfall in May was followed by rainfall in mid-June and July which resulted in late flushes of weeds such as wild millet which were difficult to control. The Seed Farm site received in excess of 100 mm of irrigation.

The 2003 crop season in the Saskatoon region was a marked improvement over 2002. We received 50-60 mm of rain in April and another 50 mm in early July. The remaining months saw below-normal rainfall. However, the timely rainfalls meant that yields were reduced by approximately 30% compared to the long-term average not the 75-90% reductions we saw in 2002. The Seed Farm site received approximately 100 mm of irrigation.

The 2004 growing season was characterized by cool-moist conditions which resulted in excess straw production and delayed heading and maturity. The delayed harvest was a challenge with samples being harvested a few days prior to first snow-fall in mid-October.

SPRING SPELT WHEAT REGISTRATION TESTING (2002 TO 2006)

Based on the 2002 field-test results, the selected awnless spring spelt lines out-yielded CDC Nexon, with improved straw strength and (in a majority of cases) reduced height (Table 1). The experimental lines tended to be higher in protein content than the checks. In one case, by nearly 2%.

The quality analyses for the 2002 test are presented in Table 2. The spring spelt lines exhibited weak (desirable for spelt) gluten properties but yet reasonable bread baking properties. Three lines from the 2002 test were dropped due to agronomic or end-use quality weaknesses.
The 2003 Registration Test consisted of two check cultivars and 6 experimental lines. Two of these lines were sublines from 99SPELT9 (Y and Z) (Table 3). These sublines were created when we observed two distinct biotypes when producing breeder long rows in 2002. The Z-biotype has the desirable gliadin profile we are seeking. Based on the 2003 data, the Z-line was higher, yielding, earlier maturing and shorter than CDC Nexon. The remaining candidate lines continued

to out-yield CDC Nexon for a second year in a row, with improved straw strength and (in a majority of cases) reduced height. The yield increases over CDC Nexon were in the range of 12-16% in 2003 (Table 3).

Four of Spelt lines from the 2003 Registration Test (entries 5 to 8) were dropped due to segregation among Long or Medium Breeder Rows for vernalization requirement. The 2004 Test consisted of two check cultivars and seven experimental lines. Four of these lines were sublines from two lines tested in 2001-2003. Two new lines from the CDC project were entered as first year lines in 2004 (Table 5).

The line 99SPELT9Z was tested for a second year in 2004 (Table 5) and continued to be higher, yielding, earlier maturing and shorter than CDC Nexon.

The quality analyses for the 2004 test are presented in Table 6. The spring spelt lines continued to exhibit weak (desirable for spelt) gluten properties but yet reasonable bread baking properties.

The 2005 Test consisted of two check cultivars and five experimental lines. No new lines from the CDC project were entered as first year lines in 2005 (Table 7). Quality evaluation data is presented in Table 8.

Based on three years of promising results the line 99SPELT9Z was brought forward for Registration in 2006. The multi-year agronomic data is summarized in Table 9. 99SPELT9-Z was Supported for Registration in February 2006.

99SPELT9Z was selected from the cross RL5407/Common winter spelt. RL5407 is an awned, grey-black hulled spring spelt accession similar to CDC Nexon in agronomic profile. Seed of the Common winter spelt wheat parent was purchased from a retail outlet. When sown in the spring of 1992 the winter spelt homogeneously failed to head during the growing season. Consequently this line was fall sown in the field (courtesy D.B. Fowler; CDC), providing pollen for the cross made with RL5407 during the summer of 1993. The F1 generation was grown in a greenhouse during the winter of 1993/1994. The F2, F3 and F4 generations were grown in bulk plots at Saskatoon during the 1994, 1995 and 1996 crop seasons. F4-derived F5 head rows were grown in a dryland nursery in 1997. 99SPELT9Z is derived from one of those bulked F_5 head rows. The F2 to F4 bulk plots were combine-harvested, dehulled and the grain sieved in order to apply selection pressure against delayed maturity. The F5 rows were selected on the basis of earlier heading relative to CDC Nexon, lack of awns, reduced height and lodging. The candidate line was evaluated in an unreplicated yield plot nursery in 1998 and selected using the same criteria as in 1997, with the addition yield, grain protein concentration and SDS sedimentation volume. 99SPELT9 was subsequently evaluated in local yield tests (1999 and 2000; SY=8) in and in the Private Spring Spelt Wheat Test from 2003 to 2005. In 2001 and 2002 99SPELT9Z was tested as a component of 99SPELT9 in the Private Spring Spelt Wheat Test. When lined out for breeder row production in 2002, 99SPELT9 consisted of two morpho-types (Y and Z) for plant height and days to head. The differences were slight (1 day difference in heading and 2 cm in height) but none-the-less distinct. In addition, the two sub-lines differed in omega gliadin profile.

AREA OF ADAPTATION: Longer crop season wheat growing areas of Saskatchewan and Alberta.

STRENGTHS: Increased yield coupled with earlier maturity, stronger straw and higher grain protein content. Lack of awns will facilitate grain handling and processing. Higher grain protein content. Intermediate reaction to FHB.
WEAKNESSES: Susceptible to stem rust, moderately susceptible to common bunt.
DESCRIPTION: 99SPELT9Z spring spelt is awnless, hollow-stemmed with earlier maturity than the spelt check cultivar CDC Nexon (Table 9). In three years of testing in the Private Spring Spelt Wheat Test, 99SPELT9Z was 21 and 10% higher yielding (hull on basis) than CDC Nexon and AC Barrie (CWRS), respectively. 99SPELT9Z was shorter-strawed and less prone to lodging than CDC Nexon. (Table1). 99SPELT9Z was earlier maturing (2 days) than CDC Nexon. 99SPELT9Z was similar to CDC Nexon for test weight, kernel weight and threshability (Table 9). 99SPELT9Z gave an intermediate reaction to prevalent races of leaf rust but was susceptible to stem rust. 99SPELT9Z was resistant to loose smut. 99SPELT9Z was moderately susceptible to bunt, with infection levels similar to those of AC Barrie and higher than those of CDC Nexon. The average FHB index level for 99SPELT9Z was similar to that of CDC Nexon and lower than that of AC Barrie.

For 2006 a 10-entry Registration Test is being grown. The line 99SPELT9Z was added as a third check. The line 03SPELT4 is a third year entry in 2006. This line lodges less than CDC Nexon and 99SPELT9Z and is higher yielding with slightly shorter straw and higher protein content.

SPELT WHEAT BREEDER SEED PRODUCTION (2002 to 2006)

Long breeder rows of 99SPELT9 (100 rows x 50 m) were produced in 2002 and short breeder rows (200 x 1.3 m) for the 2000 series lines. There were two biotypes in the 99SPELT9 long breeder rows, these were present in near-equal proportions. As a result we produced two subsets of 99SPELT9 and entered these in the 2003 Spelt Private Registration Test.

Long breeder rows of two spelt lines (00SPELT8 and 00SPELT20) were produced in 2003 and medium breeder rows (120 x 3.6 m) for another two lines (00SPELT5 and 00SPELT17). We observed multiple biotypes in all four experimental lines. The decision was made to reselect all four lines. The reason for the variability within experimental lines is not clear. However, drought conditions in 2002 made it difficult to assess morphological differences due to re-growth in short breeder rows. The spring x winter parentage of these lines seems to have resulted in minor vernalization genes resulting in residual heterozygosity which could not be picked up at the plot level but was apparent once lining-out took place. In 2004, two biotypes for each of 00SPELT8 and 20 were entered in the Registration Test. The remaining two lines had a random subsample of medium breeder row-derived lines yield tested in pre-registration trials in 2004.

A breeder plot of 99SPELT9Z was grown in 2004. Despite the poor growing and harvest conditions a reasonable amount of grain (300 kg) was produced. This breeder seed was stored pending the registration of the line in late 2006 and its potential release to Select Seed growers in 2007.

In 2005 short breeder rows were produced for the four second year entries in the Registration Test. In 2006 medium breeder rows of 03SPELT4 were planted.

PRE-REGISTRATION SPELT YIELD TESTS

2003

Of the spelt breeding lines first grown in an unreplicated test in 2002, five were yield-tested in a replicated test at three sites in 2003 (Table 10). These lines are from a cross with PGR8801 a strong strawed but hard-grained spelt line we identified in our initial evaluation of spring spelt germplasm. The line 03SPELT4 was identified in this trial

Two of the five lines were retained for quality evaluation (entries 3 and 6). Based on preliminary tests, both lines fit the desired spelt quality profile and were advanced to the 2004 Registration Test.

2004

Lines developed as medium and long breeder rows in 2003 were tested in two replicated tests (2 reps each) at the Kernen Farm in 2004. The cool, wet growing conditions in 2004 resulted in severe lodging. Severely lodged lines were not harvested. The data presented in Tables 11 and 12 are for lines with better straw strength than the spelt checks. A significant number of these lines are higher yielding than the spelt check cultivars. One line (Table 12) produced in excess of seven metric tons of hulled grain. This is the highest spelt yield we have observed to date. The more promising lines underwent quality evaluation (Tables 13 &14). The lines selected on the basis of improved agronomic performance met the quality criteria for spelt wheat: soft endosperm (lower SKCS Hardness Index values) coupled with higher protein levels and weaker gluten characteristics (low SDS sedimentation values) and weaker doughs (lower mixograph values). The 2004 samples had a wide range of Falling Number values (especially Test#1) with a significant number of lines having higher FN values than CDC Nexon and 99SPELT9Z.

In 2005 lines selected from the 2004 trials were re-tested at three sites (Table 16). In addition to the 04 series lines, 19 lines identified in unreplicated trials in 2004 were advanced for testing in 2005. Good lodging differential was obtained in 2005 along with high yields. A number of early heading and maturing lines were identified (eg 04SPELT48 and 49). These two high yielding lines along with four others were advanced to the 2006 Registration Test.

In 2006 five 05 series spelt lines that were not entered in the Registration Test were planted in a replicated trial at three sites.

SPRING SPELT BREEDING POPULATIONS:

A small number (<20) of homozygous spelt breeding lines were grown in an unreplicated test in 2002. These lines were from a cross with PGR8801 a strong strawed spelt line we identified in our initial evaluation of spring spelt germplasm. The most promising lines were grown in a replicated test in 2003 as indicated in the previous section (Table 10).

Approximately 1,600 Spring spelt lines in the F_4 generation were grown in hills in 2002. Material that normally would have been grown in rows was seeded in hills in order to fit the nursery into an irrigated field. Thus, we delayed the yield-testing phase by one year (from 2003 to 2004) for

this new cycle of breeding material. I felt it prudent to advance the material a generation without putting it at risk. This strategy was used for all our nurseries for the alternative wheats, thus we had a significant number of head rows in 2003 but no unreplicated trials. A number of populations were moved forward in bulk populations as F2's in 2002. These populations were from crosses between 99SPELT9 and a number of the 2000 series lines evaluated in the 2001 and 2002 Registration Test.

In 2003, nearly 800 rows of spring spelt F5's were grown under partially-irrigated conditions. Of those 800 rows, 174 were harvested after selection relative to 99SPELT9 for height and heading time. These 174 lines were subsequently screened for protein profile and 26 selected lines were grown in un-replicated tests in 2004.

Four populations were moved forward in bulk populations as F2's or F3's in 2003. These populations were from crosses between 99SPELT9 and a number of the 2000 series lines. One new cross was made during the summer of 2003.

In 2004, in addition to the 26 lines advanced from 2003, approximately 120 lines obtained from 2003 medium Breeder Rows were tested in unreplicated tests. In excess of 70% of these lines were culled on the basis of lodging in 2004. Five populations were moved forward as bulks in 2004. One F5 population was grown as hills and selected on the basis of reduced straw length and lodging. Four new populations were grown as F1's in the field in 2004. No unreplicated trials were grown in 2005. Two F5 populations were grown as hills and selections were subsequently planted in F6 hills in 2006. In addition to the F6 populations, six populations in the F2 to F4 generations were grown as bulks in 2006 and three new populations were initiated.

EMMER-DURUM DUAL PURPOSE WHEATS

In an earlier project we crossed an emmer line with good baking quality with WB881 a strong gluten semi dwarf durum. Nearly 400 lines were advanced in a greenhouse during the winter of 1998/1999 to the F4 and were grown in head-rows in 1999. These lines were screened for threshability and SDS sedimentation and the 29 most promising lines were eventually tested in a replicated trial at three sites in 2000. The objective was to develop yellow pigmented durum-type baking wheat with good pasta quality. Eight of the lines were retained for baking tests. These lines were early-maturing and short strawed but lower-yielding than Kyle durum. However, they were similar in yield to WB881 one of the parents in the cross. The main problem with these lines appeared to be susceptibility to leaf blight (tan spot and Septoria), a trait inherited from the emmer parent and WB881.

Eight lines initially tested in 2000 were retested in 2002 (Table 17). In addition 8 new lines (02 series) were evaluated in 2002. A majority of the 02 series lines were higher-yielding than the 00 series lines with some having better yellow pigment (YP) scores (closer to the 3 durum checks). However, higher yield came at the expense of protein content. The EB lines were susceptible to leaf blight. This is not surprising since both parents are susceptible. Our objective was to develop improved breeding material to address this weakness. When the EB lines were re-tested in the field in 2003 (Table 18) we obtained relative (to the checks) grain yields of the EB lines that were similar to those obtained in 2002. The EB lines yielded in the range of the durum parent WB881

but 12 to 27% less than CWAD Kyle and AC Navigator. The EB lines tended to be earlier maturing and shorter strawed than Kyle durum.

The results of baking tests conducted on composite samples grown in 2002 (Table 19) demonstrated that some of the EB lines had loaf volumes and quality very similar to those of the CWRS control AC Barrie and superior to the CWAD controls.

JOINT PROJECT WITH THE GRAIN RESEARCH LAB OF THE CGC

Based on initial results from the CDC Quality lab the GRL at the CGC was approached to determine if researchers there would be interested in assessing the pasta and baking quality of the EB lines. During the spring and summer of 2002 the GRL Durum and Bread Baking groups (courtesy of Drs. Dexter, Preston and Marchylo) evaluated the eight 2000 series EB lines and selected checks (grown in 2001) for pasta and baking quality. The results were very encouraging. The CDC does not have routine pasta-testing capabilities, thus we did not know how this material would perform in pasta production. We did know that it baked at a level equal to CWRS wheat (AC Barrie). With the exception of spaghetti color, the EB lines were superior to the durum parent for spaghetti quality.

Approximately 10% of durum is used for baking in Italy, double the amount a decade ago (Schlichting et al. 2002). The results of the GRL testing were presented at a conference in late 2002: "Quality characterization of lines from a cross between emmer (T. dicoccum) and durum (T. durum)wheat" by L.M. Schlichting, J.E. Dexter, K.R. Preston, N.M. Edwards, B.A. Marchylo, P. Hucl and C.E. Perron.

During the spring and summer of 2003 the GRL Durum and Bread Baking groups evaluated the EB lines field-tested in 2002. The results of the second year of testing confirmed the findings based on the testing of the 2001 crop. As was the case with the first year's samples, with the exception of spaghetti color, the EB lines were superior to the durum parent for spaghetti quality.

EMMER-DURUM BREEDING POPULATIONS

A set of 30 EB lines were grown in an unreplicated test in 2002. Approximately 1/3 of the lines were retained for further evaluation. Those lines were tested for SDS sedimentation volume, yellow pigment and protein content prior to the 2003 field-testing season. None of these lines showed an improvement over existing EB lines in replicated yield trials and were thus not advanced for further testing in 2003.

A series of 160 F_6 lines were grown in an irrigated hill nursery in 2002. Single spike selections were made for evaluation in 157 F7 rows in 2003. Approximately half of those lines were harvested for further testing by Dr. Pozniak. This material is from a backcross to the durum parent.

We made crosses to better-adapted durum parents in 2001 and moved those populations forward in F3 bulk populations in 2002. These populations were grown as F4's in circa 400 hills in 2002. These lines were grown in rows in 2004. In addition, we produced a small DH population in

2002. This DH population was grown in increase plots/rows under irrigation in 2003 in order to produce enough seed for yield and quality testing in 2004.

The breeding lines and doubled haploid lines under development were transferred to the CDC Durum breeding program for further evaluation. Due to severe lodging in 2004 much of this material was culled and remaining lines re-evaluated in 2005. Large-scale increases (12 kg of grain harvested per plot) were grown in 2004 to provide seed for further grain quality processing, should the need arise. However, due to excessive frost damage the samples could not be used.

Selected EB DH lines and lines developed by further crossing to CWAD via the modified bulk method have been incorporated into an M.Sc project supervised by Dr. Pozniak.

EINKORN WHEAT

In 2002 a series of einkorn wheat lines developed by the CDC were evaluated in a replicated test (Table 20). One of four sites was lost to poor emergence. The line 'TM23' is our long-term hulled check. Uno (trt3) is a soft-glumed (partially-threshable) line that was selected from the USDA wheat collection. Uno was 33% lower yielding than TM23 in 2002. Assuming 30% hull content in TM23 and less than half the threshability of Uno, this leaves a net yield deficit of approximately 20% for Uno. The experimental lines in the treatment series 9 to 15 are soft-glumed. A number of lines (eg trts 9 to 13) were up to 20% higher yielding than Uno thus closing the yield gap with TM23. One of the lines (2002EINK5) has yellow-pigment content similar to Uno. Of the 2000 series hulled lines, 2000EINK1 continued to perform very well. Based on the 2002 data we have made significant yield gains for both hulled and free-threshing einkorns.

A series of 180 einkorn lines were tested in unreplicated tests in 2002, 27 of those lines were advanced for quality evaluation.

One of the objectives of this project was to identify high lutein content einkorn lines. 'Uno' represented the higher end for material we had been working with. In early 2002 we screened a collection of 200 or so spring einkorns that had been grown at the CDC in the mid-1990's for yellow pigment content and SDS sedimentation volume. There are reports of einkorns with better bread baking quality in the literature. We opted to test for SDS sedimentation at the same time we were screening for yellow pigment levels. We advanced approximately 60 lines for seed multiplication and retesting in 2002. Forty of the lines were grown in increase plots the remainder in rows. We identified a number of lines that show a significant increase (>50%) in pigment content. Likewise, we identified 9 einkorn accessions with double the SDS sedimentation volume of Uno or TM23.

Detailed quality analyses were carried out on selected lines field-tested in 2002 (Table 21). Although none of the einkorn lines produced a loaf quality similar to the bread wheat control, they produced a yellow crumb color and in one case (entry 13) a very yellow crumb, this being correlated with the flour slurry color (b value) measured on the Hunter-Lab apparatus. The flavor of most einkorn breads was sweet-nutty.

In 2003 a new series of einkorn lines developed by the CDC were evaluated in a replicated test at four sites (Table 22). Uno was 45% lower yielding than TM23 in 2003. Assuming a hull content of 30% in TM23 and less than half the threshability of Uno, this leaves a net yield deficit in excess of 20% for Uno. The spike morphology of the soft-glumed accessions is associated with reduced spike length, thus reduced seed set sites. This appears to limit the yield potential of partially-threshing einkorn. Based on the best new lines tested in 2002 and 2003 we have managed to increase the grain yield of soft-glumed einkorn by nearly 20% over the parent, Uno (Table 23). We retained two hulled lines in the 2003 trial. These two lines showed a yield advantage over TM23 in 2000-2003 and slightly higher yellow pigment levels.

As indicated earlier, we identified a number of lines that showed a significant increase (>50%) in yellow pigment content. These high pigment lines appeared to have a greenish tinge to their pigments extract. We modified a chlorophyll assay normally used for canola and determined that these very high pigment lines were in fact high in grain chlorophyll content. When grown out in

2003 we determined that these lines were late-heading and maturing. Lines that had acceptable maturity were subjected to replicated testing for yellow pigment content and SDS sedimentation volume (Table 22b). There are lines that produced higher levels of yellow pigment (twice that of TM23) and others that had SDS sedimentation levels double or triple that of TM23 and Uno. We started introgressing the improved pigment levels and protein quality traits into elite lines. The first set of crosses ere made during the summer of 2003 and the F1 hybrids were grown in the greenhouse.

In 2004, Uno was 30% lower yielding than TM23. Assuming a hull content of 30% in TM23 and 60% lower threshability than Uno, this leaves a net yield deficit of roughly 15 to 20% for Uno. The spike morphology of the soft-glumed accessions is associated with reduced spike length, thus reduced seed set sites. The three experimental lines (Entries 9, 10 and 11) failed to show a yield advantage over Uno in 2004 (Table 23). This appears, in part, to result from reduced plant stands. The two hulled einkorn experimental lines (Entries 4 and 5) did not yield as well as TM23 in 2004 but produced higher yellow pigment values (Table 24). Entries 12 to 22 comprise einkorn wheat accessions selected on the basis of high sedimentation volume and/or higher lutein content. These lines were all hulled and lower yielding (20 to 40%) than TM23. These lines were, in general, later-maturing and taller than TM23 (Table 23). These lines maintained their higher SDS sedimentation and/or higher lutein content relative to TM23 and Uno in 2004 (Table 24). The sedimentation volume of some lines was 3 to 4-fold that of TM23. The higher sedimentation volumes were reflected by the stronger dough properties as measured by the Mixograph (Table 24). Entries 13 and 14 had lutein levels that were twice as high as those of TM23 and four times higher than those of AC Barrie common wheat. The lines with higher pigment levels tended to ($r=0.87^{**}$) have harder kernels (higher SKCS HI value). Interestingly, the einkorn lines tended to have higher Falling Number values than AC Barrie, some exceeding 700 sec. We had not conducted FN determinations on einkorn wheat prior to this experiment. The reason for the high FN values has not been determined. The very fine particle size of the einkorn flour and meal might be involved. We determined polyphenol oxidase (PPO) levels on a composite sample for each line. The einkorn lines tended to have higher PPO levels than AC Barrie. Higher PPO levels are associated with dough darkening, undesirable in noodle processing.

Detailed cake baking quality analyses were carried out on selected lines field-tested in 2003 (Table 25). Although none of the einkorn lines produced a cake quality similar to that of the common wheat pastry flour control, they produced a yellow crumb color and a very yellow crust, this being correlated with the flour slurry color (b value) measured on the Hunter-Lab apparatus. The flavor of most einkorn breads was sweet-nutty.

The Einkorn wheat lines selected for higher sedimentation volume in 2002 and 2003 were subjected to larger scale quality tests in early 2004 (Table 25). The Einkorn lines had a lower flour yield than AC Barrie common wheat. The Einkorn lines tended to have higher flour ash concentrations and slightly darker flours than AC Barrie. The flour slurries were quite yellow as a result of higher lutein levels (high b-values). Farinograph water absorption levels were lower in Eeinkorn, as might be expected from very soft endosperm wheat. The dough mixing times and Farinograph characteristics of einkorn were indicative of weaker gluten characteristics. The selected accessions, however, were twice as strong as TM23 and Uno (lower MTI, higher BWID at 5 min). Interestingly, a number of lines produced loaf volumes approaching those of AC Barrie

(Table 25). Thus it should be possible to develop Einkorn cultivars capable of producing pan breads and buns. The darker crumb color (lower indices) of the einkorn loaves is a direct result of the high lutein levels and is not a negative.

A series of 1,500 F_4 lines were grown in an irrigated hill nursery in 2002. In excess of 500 single spike selections were made in 2002 and planted in head-rows in 2003. Of those, roughly 10% were selected and harvested and grown in unreplicated tests in 2004. Of those lines, 25 were retained based on agronomic results and were evaluated for quality characteristics. Subsequently, 18 of these lines were tested in a replicated trial in 2005. Only one of the 05 series lines performed well (Table 26) and warranted quality evaluation (Table 27). The high lutein and or high SDS sedimentation einkorn lines yielded between 80 and 100% of TM23 (Table 26). The longer frost-free growing season in 2005 did not penalize the later-maturing einkorn lines as much as the early fall frost marred 2004 crop season.

The F2 populations from four new crosses were grown in the field in 2004. A further seven crosses were made during the summer of 2004 and the F1 plants were grown in the greenhouse during the winter of 2004/2005. For both sets of F1's we had to vernalize the hybrid plants, resulting in one generation being grown over the winter. In 2006, 10 einkorn populations were grown in bulk as F3 or F4 populations These populations are from crosses between agronomically adapted lines bred at the CDC and the high lutein, baking quality accessions identified as part of this project.

PUFFING WHEATS

In excess of 2,500 puffing wheat experimental lines were grown in head-rows in 2000. Approximately 30% of those lines were harvested. This material was screened for seed size. These experimental lines were from nine populations in which we were attempting to develop large-seeded lines with a rice-shaped kernel. In excess of 180 lines selected for flatter, longer seed shape were subsequently grown in unreplicated trials in 2001. Of the 180 lines, approximately 20 were long-seeded with high seed weight. Those lines were yield-tested in 2002 (Table 28). We appear to have recovered a number of lines with reasonable yield and high kernel weights.

Of 900 lines grown in head rows and screened for seed weight in 2001, approximately 120 were grown in unreplicated tests in 2002. Lines selected from this group as well as lines retained from the 2002 replicated trial were evaluated in 2003 (Table 29). A number of those lines had kernel weights approaching 70 mg and longer kernels than checks (entries 1 to 3).

Eight advanced generation lines (02 and 03 series) developed during the course of this project were evaluated at four sites in 2004. These lines yielded less than the CWAD cultivar AC Avonlea, as was the case in 2003. A number of the lines (eg Entry 11) continued to yield significantly higher than the large-seeded controls (Entries 2&3) (Table 30).

Approximately 1,700 F_4 and F_5 lines were grown in hills in 2002 and 900 of those lines were grown in head rows in the F5 and F6 generations in 2003. A quarter of those lines were selected based on agronomic type. Of the 900 head rows grown in 2003, 90 were selected and grown in

unreplicated plots in 2004. Of those lines, 80 were evaluated for kernel weight and kernel length and 19 were grown as 05 series lines in a replicated test in 2005 (Table 31).

Selections from F4 hills grown in 2003 were advanced to head-rows in 2004. Of these lines, 200 were harvested and following selection for kernel type and size, 50 were tested in unreplicated trials in 2005 and of those six are being tested in a replicated trial at three sites along with 10 other entries in 2006.

Three new populations were initiated during 2003-2004 and two new populations in 2005. These populations were in the F2 and F4/F5 generations in 2006. Four new populations were initiated in 2006.

Conclusions and Recommendations

In 2004, grain yields of spring spelt wheat experimental lines exceeded 6 metric tones in trials grown at Saskatoon. The high rainfall condition in 2004 and 2005 resulted in good yield potential expression. Lines in the Spring Spelt Registration Test out-yielded the CDC Nexon control by 20-30%. Those yield differentials are not expected to be maintained under average growing conditions but a 10-20% yield spread is a realistic expectation.

If spelt wheat is to be wider adapted to Saskatchewan further breeding efforts will be required to reduce days to maturity and straw length and improve disease resistance. In our initial evaluation of spring spelt accessions we found that a majority of the germplasm was highly resistant to common bunt. The lines developed by crossing spring with winter spelt wheat have tended to be susceptible to the disease. This suggests that the two winter spelt wheat parents we used are susceptible to common bunt. Thus, recovering the bunt resistance levels of CDC Nexon and RL5407 (He and Hughes, 2003) via backcrossing is desirable. Furthermore, the vast majority of spelt wheat is susceptible to stem rust. However, a limited number of lines are known to carry some resistance (McVey, 1990) and these could be used as parents.

The use of emmer wheat to as a source of gluten proteins conferring bread wheat equivalent baking quality to durum wheat was demonstrated by this project. Lines with good baking quality also produced acceptable pasta. Thus, we demonstrated that it is possible to develop dual purpose durum without resorting to the introgression of hexaploid gliadins or glutenins. Emmer is closely related to durum wheat and carries the same genomes (AB). Doubled haploid lines that had three doses of CWAD parentage were developed as well as inbred lines with two doses. This material was screened for baking quality and yellow pigment content and then transferred to the CDC Durum breeding program.

During the course of this project we have identified einkorn lines with bread-making potential and higher levels of lutein (see photo on last page). These lines are, however, 20% lower yielding and one week later maturing than our agronomic check 'TM23'. Einkorn lines which combine baking quality with agronomic performance are needed.

Large-seeded lines from crosses between durum and Khorasan (T. turgidum type turanicum) and Polish wheat (T. turgidum type polonicum) were developed and evaluated for agronomic

performance. Large seeded durum x Khorasan lines with kernels 18 to 19 mg heavier than those of AC Avonlea CWAD were selected. These lines were 4 to 13% lower yielding than AC Avonlea in 2005 trials (3 sites) but 13 to 20% higher yielding than our internal check line initially developed in 1999 (99PUFF1). These lines are 30-40 cm shorter than the Khorasan wheat check (PI211691). Thus agronomically competitive lines have been developed with Khorasan kernel characteristics. Selection for the rice-shaped kernel resulted in a non-arched kernel which should reduce grain-cracking during the puffing process. Lines with the rice-shaped kernels tended to have lower test weights. This is likely a result of the seed shape. This should not be surprising as rice grain has an average test weight of approximately 52-55 kg/hL while naked oat averages in the same range. Thus, a test weight of approximately 70 kg/hL would be realistic for a long, narrow wheat kernel. Lines (eg 05PUFF7) with large rice-shaped kernels have been developed but tended to be 20% lower yielding than the CWAD check variety AC Avonlea. The line 05PUFF7 was slightly higher yielding than our original selection (02PUFF16) but has a heavier, longer kernel along with higher protein content and higher yellow pigment content of the grain. In conclusion, Khorasan-type puffing wheat could be commercialized using the most promising lines developed during the course of this project. Material with a polonicum-type shape is still limited by a 20% yield penalty. Thus, a significant premium would be needed in the market-place to compensate growers. Thus, further breeding efforts will be required for the latter material.

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Administrative and Other Aspects:

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H. Braitenbach (Tech) (September 6, 2002 to May 31, 2003) - 100%

(October 1, 2003 to May 31, 2004) - 100%
(October 1 to November 30, 2004; February 1 to May 31, 2005) - 100%
(October 1, 2005 to May 18, 2006) - 100%

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Equipment: None purchased for this project.
Project Developed Materials: Nil.
Project photos: see attached photo of loaves baked from einkorn wheat selections.
Expense statement: under separate cover from University of Saskatchewan Financial Services.

Table 1. Summary of agronomic and disease data for the 2002 Spring Spelt Registration Test grown at six sites in western Canada

		Grain Yield	% CDC Nxn	Heading days	Maturity days	Height cm	Lodging 1 to 9	T.wt kg/hL	K.wt mg	Thresh. %	Protein %	Leaf rust	Stem rust	Leaf blight 1 to 9	Bunt %	2001 Loose smut %
1	AC BARRIE	2096	**96.6**	58.1	99.8	72.1	1.0	78.5	34.9	96.4	16.2	MS	R	3.3	0.0	36
2	CDC Nexon	2170	**100.0**	63.9	107.1	92.4	8.3	76.7	38.2	51.5	16.3	R-	S	3.0	1.5	0
3	99SPELT9	2295	**105.8**	63.2	105.5	91.5	4.0	75.5	38.3	53.9	16.9	R-	S	2.7	3.2	0
4	2000SPELT5	2722	**125.4**	63.0	108.3	89.4	6.0	75.8	41.6	45.6	16.6	R-	S	0.7	14.7	2
5	2000SPELT6	2493	**114.9**	64.2	105.7	88.3	6.0	75.8	41.8	43.2	16.7	R-	S	3.3	1.9	33
6	2000SPELT8	2651	**122.2**	63.7	106.5	90.6	6.7	76.0	38.6	35.9	17.1	MR	S	2.7	9.5	3
7	2000SPELT9	2328	**107.3**	61.9	106.0	83.6	6.3	75.2	36.8	35.5	17.9	MR	S	3.0	2.0	3
8	2000SPELT17	2486	**114.6**	62.4	106.7	88.0	5.3	76.4	41.2	47.7	16.8	MR	S	1.7	19.1	0
9	2000SPELT20	2338	**107.7**	63.0	106.3	84.6	5.0	75.5	36.8	41.6	18.0	R-	S	3.0	2.4	7
10	2000SPELT21	2607	**120.1**	64.5	107.0	88.7	7.3	74.2	42.3	36.2	16.7	MR	S	0.7	4.3	53
	Number of sites	6		5	4	5	1	6	6	5	6			1		

Table 2. Quality analyses for the 2002 Spring Spelt Registration Test, based on a quality composite across sites.

Entry		Grain Protein (%)	Flour Protein (%)	Protein loss (%)	Flour Yield (%)	Flour Ash (%)	Falling Number (sec)	Amylo peak (BU)	Starch Damage (%)	PSI (%)	KVD
1	AC Barrie	15.4	14.9	0.6	77.6	0.60	564	485	6.4	47	
2	CDC Nexon	15.4	14.7	0.8	78.6	0.60	254	95	3.4	60	Spelt
3	99SPELT9	16.0	15.3	0.6	77.0	0.71	256	55	3.7	56	Spelt
4	00SPELT5	15.2	14.4	0.7	77.5	0.68	295	70	3.9	58	Spelt
5	00SPELT6	15.5	14.6	1.0	76.8	0.69	281	113	3.4	61	Spelt
6	00SPELT8	15.7	15.0	0.8	75.0	0.60	358	225	3.7	56	Spelt
7	00SPELT9	17.0	15.9	1.1	77.2	0.72	343	135	4.2	52	Spelt
8	00SPELT17	15.6	14.5	1.1	76.7	0.68	317	100	3.7	55	Spelt
9	00SPELT20	16.7	15.9	0.8	77.2	0.73	432	220	4.2	57	Spelt
10	00SPELT21	15.5	14.6	0.9	76.4	0.71	313	130	4.2	56	Spelt

Table 2 continued. Flour, dough and baking characteristics of entries in the 2002 Spring Spelt Registration Test

Entry		Hunter-Lab Flour Color L	a	b	Refl 540	Hunter-Lab Flour Slurry Color L	a	b	Refl 540
1	AC Barrie	88.17	0.50	9.70	77.60	80.92	0.66	12.56	65.40
2	CDC Bavaria	89.61	0.37	8.51	80.29	79.69	0.79	13.58	63.42
3	99SPELT9	89.40	0.28	8.88	80.05	79.45	0.79	13.96	63.20
4	00SPELT5	89.42	0.23	9.10	80.18	79.39	0.58	14.29	63.31
5	00SPELT6	89.53	0.30	8.76	80.32	78.60	0.87	14.46	61.93
6	00SPELT8	89.80	0.30	8.62	80.73	79.89	0.67	13.85	63.91
7	00SPELT9	89.11	0.40	8.29	79.27	78.39	1.10	13.27	61.11
8	00SPELT17	89.70	0.24	9.20	80.67	79.92	0.64	14.60	64.14
9	00SPELT20	89.03	0.43	8.38	79.12	78.58	1.06	13.24	61.47
10	00SPELT21	89.08	0.27	9.30	79.51	78.57	0.92	14.73	62.45

Entry		Farinograph FAbs %	Farinograph DDT min	Farinograph MTI	Farinograph STA min	CSP Bake Test LV cc	Appear 1 to 10	Structure	Crumb Color	Energy Whr/Kg	DDT min	Dough
1	AC Barrie	67.5	5.5	25	9.5	1033	7.5	6.0	6.0	6.9	3.9	3.0
2	CDC Bavaria	62.2	3.8	70	4.3	988	7.0	5.3	5.0	7.2	3.9	2.5
3	99SPELT9	64.6	3.5	80	4.2	990	6.0	4.5	4.0	5.6	3.0	2.5
4	00SPELT5	63.6	2.0	90	3.8	910	5.5	4.3	4.3	4.8	2.4	2.5
5	00SPELT6	64.4	1.2	130	2.0	905	5.5	3.5	3.0	3.8	1.8	2.0
6	00SPELT8	64.6	2.7	95	2.9	993	7.0	5.3	5.0	4.6	2.4	2.0
7	00SPELT9	66.8	2.4	85	2.7	1010	6.5	3.8	4.0	4.8	2.4	2.5
8	00SPELT17	65.4	2.4	95	3.2	940	6.3	5.0	4.5	4.7	2.4	2.0
9	00SPELT20	66.6	2.8	85	3.6	990	6.0	5.0	4.5	5.4	2.7	2.5
10	00SPELT21	63.6	1.2	95	2.9	880	5.0	5.0	5.0	4.3	2.1	2.5

Table 3. Summary of 2003 Agronomic and disease data for the 2003 Spring Spelt Registration Test grown at six sites in western Canada

Entry	NAME	Grain Yield	% CDC Nexon	Heading days	Maturity days	Height cm	T.wt kg/hL	K.wt mg	Thresh. %	Protein %	Leaf rust	Stem rust	Bunt %
1	AC BARRIE	3250	**98.0**	56.3	94.9	79.1	79.2	33.3	93.7	15.9	MRMS	MR	71
2	CDC NEXON	3316	**100.0**	63.8	96.3	108.4	74.1	36.0	28.1	16.2	S	S	11
3	99SPELT9-Y	3484	**105.1**	61.4	95.4	102.8	73.4	36.0	30.0	16.5	S	S	45
4	99SPELT9-Z	3542	**106.8**	61.1	95.5	103.5	74.0	36.0	28.3	16.6	S	S	57
5	2000SPELT5	3863	**116.5**	62.3	97.9	106.2					MS	S	74
6	2000SPELT8	3765	**113.5**	63.0	97.1	104.7					MS	S	57
7	2000SPELT17	3695	**111.4**	61.4	96.8	105.7					MRMS	S	70
8	2000SPELT20	3474	**104.8**	61.8	96.5	98.6					MS	S	53
		6		5	4	6	4	4	4	5			3 reps

Table 4. Quality analyses for selected entries in the 2003 Spring Spelt Registration Test, based on a composite across sites

Entry		WheatPro 13.5%mb (%)	Flour Pro 14.0%mb (%)	Protein loss (%)	Flour yield (%)	Flour Ash (%)	Falling number (sec)	RVA Peak (rvu)	Starch damage (%)	a-amylase (ceralpha)	SKCS (HI)	KVD
1	AC Barrie	15.0	14.4	0.6	78.8	0.48	465	170	4.95	0.072	72.5	CWRS
2	CDC Nexon	15.2	14.3	0.9	77.6	0.53	411	156	1.75	0.118	31.8	Spelt
3	99SPELT9-Y	15.6	14.4	1.2	75.9	0.53	400	150	1.55	0.123	31.3	Spelt
4	99SPELT9-Z	15.6	14.5	1.1	76.8	0.53	392	139	1.80	0.129	33.1	Spelt

		Hunter-Lab Flour Color			Flour Slurry Color			
Entry		L	a	b	L	a	b	Agtron units
1	AC Barrie	88.85	0.64	10.34	82.94	0.17	12.69	51.7
2	CDC Nexon	89.74	0.58	9.22	80.72	0.82	14.26	35.4
3	99SPELT9-Y	90.09	0.42	9.85	81.70	0.53	15.02	46.0
4	99SPELT9-Z	90.04	0.44	9.65	81.93	0.52	15.00	47.8

		Farinograph				CSP Bake Test						
Entry		FAB (%)	DDT (min)	MTI	STA	LV (cc)	Appear	Struct	CrColor	Whr/Kg	Min	Dough (1 to 5)
1	AC Barrie	63.0	5.0	32	10.5	1038	8.0	6.0	6	8.2	4.7	3.5
2	CDC Nexon	58.5	3.0	50	4.6	968	5.8	5.0	5	7.2	3.8	3.0
3	99SPELT9-Y	60.2	2.5	50	4.2	948	7.0	4.3	4	5.8	3.0	2.5
4	99SPELT9-Z	60.4	1.7	25	7.2	985	7.5	5.5	5	5.4	3.0	3.0

Table 5. Summary of Agronomic and disease data for the 2004 Spring Spelt Registration Test grown at eight sites in western Canada

Entry	NAME	Grain Yield kg/ha	% CDC Nxn	Heading days	Maturity days	Height cm	Lodging 1 to 9	K.wt mg	Thresh. %	Grain Protein %	Leaf rust	Stem rust	Bunt %	Loose smut %	FHB VRI
1	AC Barrie	4199	**118.4**	65.4	114.7	97.9	2.6	38.0	98	14.9	MR-MS	MR-R	37	44	21
2	CDC Nexon	3548	**100.0**	71.2	124.8	125.9	5.6	41.9	37	15.1	MR-MS	S	15	0	19
3	99SPELT9-Z	4364	**123.0**	69.2	120.1	123.9	3.6	43.5	33	15.6	R	S	65	0	10
4	00SPELT8-X	4347	**122.5**	70.5	124.7	121.8	4.2	44.3	26	15.6	R-	S	71	0	1
5	00SPELT8-Y	4098	**115.5**	71.5	127.2	124.0	5.0	44.9	20	culled	R-	S	43	0	2
6	00SPELT20-X	4432	**124.9**	68.9	122.7	117.4	3.6	42.4	21	16.3	R-	S	85	9	8
7	00SPELT20-Y	4633	**130.6**	69.6	123.9	118.7	4.4	41.8	23	15.9	MR	S	63	4	6
8	03SPELT1	4302	**121.3**	72.3	124.4	119.9	3.8	40.3	19	culled	MR	S	5	0	39
9	03SPELT4	4633	**130.6**	69.5	123.1	120.6	2.8	41.5	14	16.0	R	S	53	6	39
												Columbus	16	FHB 37	2
	# of sites	8		5	5	6	5	4	8	8		Neepawa	59	Teal	64
												Laura	76		
													3 reps		2 reps

Table 6. Quality analyses for selected entries in the 2004 Spring Spelt Registration Test, based on a composite across sites.

Trt		Grain Protein (%)	SDS-sedimentation (ml)	Falling number (sec)	Flour yield %	Flour protein %	Flour Ash (%)	Flour FN (sec)	RVA Pk (RVU)	Starch Damage (megazyme)	alpha-amylase (c.u.)	SKCS H.I.
1	AC Barrie	13.8	61	430	77.4	13.4	0.51	439	128	5.3	0.104	61
2	CDC Nexon	13.9	51	229	76.4	13.3	0.61	332	74	2.8	0.210	24
3	99SPELT9-Z	14.6	40	172	74.1	13.8	0.58	231	37	2.7	0.457	23
4	00SPELT8-X	14.3	27	306	74.9	13.5	0.64	346	89	3.3	0.166	38
6	00SPELT20-X	15.0	39	407	74.4	14.1	0.65	494	126	3.4	0.118	35
7	00SPELT20-Y	14.7	29	393	74.8	13.8	0.65	457	135	3.4	0.126	35
9	03SPELT4	14.7	30	339	75.6	14.1	0.58	356	86	2.7	0.198	30

		HL Flour Color			Flour Slurry Color			
Trt		L	a	b	Agtron	L	a	b
1	AC Barrie	90.58	0.76	11.71	46.6	84.55	1.12	14.79
2	CDC Nexon	91.65	0.58	9.72	29.2	82.98	1.44	15.84
3	99SPELT9-Z	92.21	0.46	10.28	43.7	84.42	1.19	16.19
4	00SPELT8-X	91.88	0.57	9.77	33.3	83.36	1.46	15.27
6	00SPELT20-X	91.66	0.61	9.40	30.4	83.11	1.56	14.97
7	00SPELT20-Y	91.63	0.63	9.34	31.3	83.28	1.56	14.75
9	03SPELT4	91.68	0.60	9.78	36.1	83.79	1.46	15.00

Table 6 continued. Dough and baking properties of selected entries in the 2004 Spring Spelt Registration Test

Trt		Farinograph FAB (%)	DDT (min)	MTI (BU)	STA (min)	CSP Bake Test LV (cc)	App	Struct	CrColor	Mixing Energy Whr/Kg	Mixing Time (min)
1	AC Barrie	61.2	4.5	40	6.8	1008	3.8	3.4	3.5	8.7	4.6
2	CDC Nexon	59.2	1.5	130	2.7	903	2.9	2.8	2.5	4.8	2.9
3	99SPELT9-Z	61.0	1.0	105	2.2	900	2.9	2.7	2.2	5.2	2.5
4	00SPELT8-X	61.1	1.0	130	2.1	853	2.7	2.6	2.2	3.1	1.7
6	00SPELT20-X	60.8	1.4	60	2.7	888	2.8	2.8	2.5	6.3	3.2
7	00SPELT20-Y	61.2	2.0	100	2.9	850	2.5	2.6	2.2	4.1	2.0
9	03SPELT4	60.6	1.0	110	2.9	898	3.2	3.0	2.7	4.4	2.0

Table 7. Summary of Agronomic and disease data for the 2005 Spring Spelt Registration Test grown at eight sites in western Canada

Entry	NAME	Grain Yield (kg/ha)	% CDC Nexon	Heading days	Maturity days	Height cm	Lodging 1 to 9	Test weight kg/hL	Kernel weight mg	Thresh-ability %	Grain Protein %	Leaf rust	Stem rust	Bunt %	Loose smut %
1	AC Barrie	3758	**110**	62.5	101.5	96.4	1.3	79.4	33.7	95.6	15.1	MR-MS	20 MR-R	61	10
2	CDC Nexon	3411	**100**	70.2	108.7	125.4	4.9	77.6	38.3	22.1	14.3	R-	40 S	11	0
3	99SPELT9-Z	4447	**130**	68.0	106.9	126.3	2.4	77.6	38.2	22.0	15.2	MR	100 S	75	6
4	00SPELT8-X	4807	**141**	68.5	107.6	121.9	3.5	79.2	39.3	17.0	15.6	MR	100 S	29	5
5	00SPELT20-X	4639	**136**	67.5	106.8	121.0	2.3	79.1	36.2	11.3	15.4	MS	100 S	65	2
6	00SPELT20-Y	4523	**133**	68.3	107.5	120.8	2.5	78.8	35.8	12.7	15.0	S	60 S	49	7
7	03SPELT4	4528	**133**	67.4	106.8	119.2	2.1	78.4	37.3	9.2	15.4	S	100 S	66	2
	# of sites	8		5	6	6	5	7	7	7	7				
													Columbus=	16	
													Neepawa=	58	
													Laura=	82	
														3 reps	

Table 8. Quality analyses for selected entries in the 2005 Spring Spelt Registration Test, based on a composite across sites.

Tmt		Protein 14%mb	SDS-sed (mL)	FN (sec)	FY 14%mb	Fpro 14%mb	Fl Ash (%)	Starch Damage (megazyme)	Alpha amylase (c.u.)	SKCS H.I.
1	AC Barrie	14.0	57	487	76.5	13.3	0.538	6.1	0.080	63
2	CDC Nexon	13.6	46	328	75.7	12.5	0.538	3.3	0.126	23
3	99SPELT9-Z	14.1	41	306	75.0	13.3	0.562	3.1	0.202	24
4	00SPELT8-X	14.5	29	391	74.4	13.6	0.576	3.7	0.087	34
5	00SPELT20-X	14.5	37	436	75.6	13.4	0.619	3.9	0.093	38
6	00SPELT20-Y	13.9	25	419	76.1	13.1	0.633	4.2	0.097	39
7	03SPELT4	14.4	31	404	76.2	13.6	0.561	3.1	0.119	28

Tmt		Hunter-Lab Flour Color L*	a*	b*	Flour Slurry Color Agtron	L	a	b
1	AC Barrie	91.08	0.42	11.89	53.0	85.19	1.21	15.48
2	CDC Nexon	92.08	0.19	9.76	38.6	83.70	1.30	16.19
3	99SPELT9-Z	92.20	0.14	10.35	44.2	84.19	1.26	16.95
4	00SPELT8-X	91.72	0.23	9.95	34.7	83.24	1.56	16.34
5	00SPELT20-X	91.73	0.23	9.63	35.0	83.38	1.46	15.59
6	00SPELT20-Y	91.59	0.26	9.57	32.3	82.98	1.53	15.19
7	03SPELT4	91.86	0.20	10.04	40.8	83.99	1.38	15.81

Tmt		Farinograph FAB (%)	DDT (min)	MTI (BU)	STA (min)	CSP Bake Test LV (cc)	App	Struct	CrColor	Mixing Energy Whr/Kg	Mixing Time (min)
1	AC Barrie	62.6	3.8	40	7.0	1070	4.0	3.3	3.5	10.0	4.9
2	CDC Nexon	57.0	1.9	60	3.0	995	3.5	3.0	3.0	5.4	2.7
3	99SPELT9-Z	58.8	1.4	70	2.4	975	3.3	2.9	2.7	5.3	2.4
4	00SPELT8-X	60.6	1.2	80	2.0	950	3.0	2.7	2.9	4.4	2.1
5	00SPELT20-X	59.0	1.0	90	1.9	855	2.5	2.1	2.5	4.6	2.2
6	00SPELT20-Y	59.6	0.9	110	1.5	913	3.0	2.6	3.0	4.4	2.0
7	03SPELT4	58.0	1.0	100	2.0	958	3.4	2.8	2.9	4.5	1.9

Table 9. Multi-year summary of agronomic data for 99SPELT9Z and check cultivars in the Private Spring Spelt Wheat Test from 2003 to 2005

NAME	Grain Yield kg/ha	% CDC Nexon	Heading days	Maturity days	Height cm	Lodging 1 to 9	Test wt kg/hL	Kernel wt mg	Threshability %	Grain Protein %
AC Barrie	3780	**110**	61.4	104.2	91.1	2.0	79.3	35.1	96.3	15.2
CDC Nexon	3435	**100**	68.4	110.8	119.9	5.3	75.7	39.4	29.6	15.1
99SPELT9-Z	**4170**	**121**	**66.1**	**108.3**	**117.9**	**3.0**	**75.5**	**39.7**	**27.9**	**15.7**
Number of trials	22		15	15	18	10	16	19	19	20

Table 10. Agronomic performance of spring spelt breeding lines first tested in replicated trials in 2003 (03 series)

ENTRY	NAME	Grain yield kg/ha	DSE days	DPM days	Height cm	Test weight kg/hL	Kernel Weight mg	Treshabili -ty %
1	CDC NEXON	4139	63.0	93.8	106.8	76.1	38.7	66
2	AC BARRIE	3493	55.0	90.7	72.3	81.2	35.9	99
3	03SPELT1	4249	63.0	93.7	101.2	73.7	38.2	38
4	03SPELT2	3980	58.5	92.8	92.0	72.0	36.3	19
5	03SPELT3	4290	60.0	92.0	93.5	71.9	37.5	34
6	03SPELT4	4504	61.7	93.5	99.0	74.2	37.8	32
7	03SPELT5	4193	61.8	94.0	98.3	70.3	36.7	12
	# of sites	3	3	3	3	2	2	2

Table 11. Agronomic performance of spring spelt breeding lines first tested in 2004 (04series) in Test 1.

			Yield (kg/ha)	DSE days	Height cm	Lodging 1 to 9	Bunt %
1	CDC Nexon		4792	70.5	117.5	7.0	6
2	99SPELT9-Z		5506	69.0	116.5	6.0	7
3	AC Barrie		4915	64.5	96.5	1.5	24
31	04SPELT28	00SPELT20LBR	5870	67.0	110.5	4.5	47
32	04SPELT29	00SPELT20LBR	5275	67.5	114.5	3.0	23
33	04SPELT30	00SPELT20LBR	5405	68.0	115.0	1.5	41
37	04SPELT34	00SPELT20LBR	6146	66.5	108.5	3.0	37
38	04SPELT35	00SPELT20LBR	6193	67.5	112.0	3.5	42
39	04SPELT36	00SPELT20LBR	5317	68.5	113.5	2.0	18
41	04SPELT38	00SPELT20LBR	6079	68.5	114.5	3.5	29
44	04SPELT41	00SPELT20LBR	5637	68.0	113.5	2.5	44
46	04SPELT43	00SPELT20LBR	5624	70.0	113.5	4.5	44
47	04SPELT44	00SPELT20LBR	5935	69.0	114.0	3.0	45
48	04SPELT45	00SPELT20LBR	6093	67.0	113.5	3.5	28
49	04SPELT46	00SPELT20LBR	6001	66.5	114.5	2.5	39
51	04SPELT48	00SPELT20LBR	6151	65.5	107.0	3.5	40
52	04SPELT49	00SPELT20LBR	6394	65.5	115.5	2.0	20
53	04SPELT50	00SPELT20LBR	5678	68.5	111.5	2.5	46
55	04SPELT52	00SPELT20LBR	5748	68.5	111.5	4.0	29
59	04SPELT56	00SPELT5MBR	6529	66.5	120.0	3.0	38
60	04SPELT57	00SPELT5MBR	6515	67.5	120.5	4.0	45
63	04SPELT60	00SPELT5MBR	6707	67.5	120.0	2.5	18
	# of sites		1	1	1	1	1

Table 12. Agronomic performance of spring spelt breeding lines first tested in 2004 (04series) in Test 2.

			Yield (kg/ha)	DSE days	Height cm	Lodging 1 to 9	Bunt %
1	CDC Nexon		4630	70.0	121.0	8.0	5
2	99SPELT9-Z		5714	68.5	123.0	7.5	32
3	AC Barrie		5640	64.0	97.5	2.0	16
4	04SPELT62	00SPELT5MBR	7117	68.5	124.0	6.0	29
6	04SPELT64	00SPELT5MBR	6561	67.0	118.5	4.0	43
9	04SPELT67	00SPELT5MBR	6538	67.0	123.0	5.0	25
12	04SPELT70	00SPELT5MBR	6212	67.0	126.0	5.0	47
14	04SPELT72	00SPELT5MBR	6741	67.5	121.0	3.0	24
15	04SPELT73	00SPELT17MBR	6263	67.0	126.0	4.5	35
20	04SPELT78	00SPELT17MBR	6669	68.5	119.0	6.5	46
21	04SPELT79	00SPELT17MBR	6381	68.0	125.0	6.0	41
22	04SPELT80	00SPELT17MBR	6390	69.0	119.5	5.0	30
24	04SPELT82	00SPELT17MBR	6267	67.0	120.5	7.0	42
25	04SPELT83	00SPELT17MBR	6022	68.5	117.5	7.0	24
28	04SPELT86	00SPELT17MBR	6214	68.0	121.5	5.0	43
29	04SPELT87	00SPELT17MBR	6098	69.0	125.5	6.0	39
30	04SPELT88	00SPELT17MBR	6615	67.0	120.5	7.0	18
33	04SPELT91	00SPELT5MBR	6152	69.5	121.5	7.0	40
35	04SPELT93	00SPELT5MBR	6729	68.0	120.5	6.5	39
44	04SPELT102	00SPELT5MBR	6587	68.5	116.5	4.5	34
48	04SPELT106	00SPELT5MBR	5962	69.0	118.5	3.5	41
52	04SPELT110	00SPELT17MBR	6392	69.5	116.5	3.5	44
54	04SPELT112	00SPELT17MBR	6259	68.0	114.5	4.5	44
62	04SPELT120	00SPELT17MBR	5988	70.0	115.0	7.0	40
	# of sites		1	1	1	1	1

Table 13. Quality evaluation of selected Spring Spelt wheat experimental lines grown at Saskatoon in 2004 (Trial#1)

ENTRY	NAME	Grain Protein %	SDS Sed ml	Falling Number sec	SKCS HI	Mixograph Time min	Mixograph Peak Height	Mixograph Peak Energy	Mixograph Band Width	Mixograph Slope after Peak	Mixograph Energy to Peak
1	CDC Nexon	15.10	53	275	24.3	1.95	53.2	308.7	8.8	-5.23	78.3
2	99SPELT9-Z	15.69	42	195	31.0	1.60	52.9	304.1	14.3	-5.32	65.4
3	AC Barrie	15.02	66	521	57.7	2.10	59.7	352.9	19.1	-3.61	96.1
32	04SPELT29	16.24	39	416	36.4	1.50	52.3	321.4	10.2	-3.28	62.3
37	04SPELT34	15.53	41	468	35.7	1.56	50.1	303.9	12.8	-3.59	62.3
39	04SPELT36	16.85	46	457	35.3	1.63	58.2	357.6	13.4	-2.25	73.6
41	04SPELT38	16.24	37	338	35.7	1.53	54.4	322.6	10.5	-4.31	65.0
44	04SPELT41	16.56	45	405	34.0	1.86	56.4	341.7	14.3	-3.33	80.0
48	04SPELT45	16.01	43	486	34.0	1.59	53.8	322.8	13.3	-4.08	67.2
51	04SPELT48	15.74	37	507	29.8	1.43	48.6	293.9	12.3	-3.25	55.0
52	04SPELT49	15.47	44	421	33.2	1.63	52.3	313.9	12.1	-3.59	66.6
55	04SPELT52	16.09	39	409	38.8	1.63	51.4	312.4	15.2	-2.97	66.6
59	04SPELT56	14.78	30	327	28.1	1.35	45.1	245.7	19.0	-4.50	47.0
63	04SPELT60	14.45	27	271	27.6	1.24	42.0	224.5	16.6	-3.77	41.0

Table 14. Quality evaluation of selected Spring Spelt wheat experimental lines grown at Saskatoon in 2004 (Trial#2)

ENTRY	NAME	Grain protein %	SDS Sedim ml	Falling Number sec	SKCS HI	Mixograph Peak	Peak Height	Total Energy	Band Width	after Peak	Energy to Peak
1	CDC Nexon	15.23	54	160	26.2	1.79	50.9	291.6	17.3	-5.61	69.6
2	99SPELT9-Z	15.69	42	175	29.9	1.48	48.5	281.8	8.3	-5.26	55.8
3	AC Barrie	15.04	65	510	60.2	2.03	57.0	334.1	16.8	-4.07	87.9
4	04SPELT62	15.08	28	321	21.3	1.30	45.7	259.6	17.7	-5.68	45.8
9	04SPELT67	14.26	31	185	27.7	1.34	42.7	238.1	17.7	-3.52	44.8
14	04SPELT72	14.50	27	227	22.0	1.30	42.3	227.2	14.9	-4.36	43.4
15	04SPELT73	15.13	32	299	28.4	1.34	47.1	275.6	14.2	-5.03	49.8
21	04SPELT79	15.06	32	279	26.7	1.18	44.8	257.5	17.7	-4.73	41.4
22	04SPELT80	15.55	35	265	31.9	1.40	50.2	284.1	17.8	-6.59	54.1
25	04SPELT83	14.93	35	224	28.2	1.37	47.8	275.7	15.5	-5.04	50.6
29	04SPELT87	15.28	34	275	27.1	1.41	45.7	269.0	13.3	-4.74	50.5
30	04SPELT88	14.94	30	268	27.4	1.27	48.6	273.9	20.7	-5.46	47.9
35	04SPELT93	14.52	26	313	24.6	1.31	42.5	234.5	18.7	-4.92	43.1
44	04SPELT102	14.17	28	209	24.3	1.36	43.4	240.2	18	-4.24	46.6
62	04SPELT120	15.02	24	308	21.5	1.27	42.3	247.0	15.2	-4.65	42.1

Table 15. Agronomic performance of selected 04 and 05 series spring spelt breeding lines tested in 2005.

ENTRY	NAME		Grain Yield kg/ha	DSE days	DPM days	Height cm	Lodging 1 to 9	Test weight Kg/hL	Kernel weight mg	Bunt %
1	CDC Nexon		3693	69.7	112.0	126.0	7.0	80.5	40.2	36
2	99SPELT9-Z		4417	67.2	105.8	125.3	4.0	80.0	40.0	46
3	AC Barrie		3502	61.5	100.8	94.7	2.0	79.4	34.3	60
6	04SPELT36	00SPELT20LBR	4279	66.3	106.0	117.2	4.5	81.5	36.1	64
7	04SPELT45	00SPELT20LBR	5404	64.7	103.5	119.3	4.0	81.4	39.6	32
8	04SPELT48	00SPELT20LBR	4987	63.3	104.3	115.5	3.3	81.7	38.5	64
9	04SPELT49	00SPELT20LBR	5215	63.7	103.5	119.5	4.3	81.4	39.1	62
10	04SPELT52	00SPELT20LBR	4715	67.0	108.5	118.2	3.3	80.5	34.5	42
11	04SPELT56	00SPELT5MBR	5036	64.8	104.3	126.3	5.3	80.9	42.5	64
17	04SPELT80	00SPELT17MBR	5067	66.2	107.0	128.2	4.3	80.9	43.3	58
20	04SPELT88	00SPELT17MBR	5035	65.8	104.3	126.3	5.0	80.7	42.8	20
23	04SPELT120	00SPELT17MBR	5478	67.3	108.8	121.3	3.8	81.3	44.4	30
24	05SPELT1	Nexon/99SPELT9	5108	66.8	103.8	126.0	4.0	79.9	38.9	54
25	05SPELT2	2000SPELT5 br	5508	67.0	108.8	124.7	4.0	80.8	44.3	32
28	05SPELT5	2000SPELT5 br	5454	68.8	113.5	126.0	4.8	80.2	42.9	50
29	05SPELT6	2000SPELT5 br	4998	67.7	110.3	127.5	6.3	79.6	46.4	54
32	05SPELT9	2000SPELT5 br	4779	66.7	111.0	128.5	6.8	80.0	41.9	46
33	05SPELT10	2000SPELT5 br	4901	66.0	106.8	125.2	5.5	79.8	42.9	66
34	05SPELT11	2000SPELT17 br	5160	66.5	109.3	123.3	5.8	81.1	43.2	58
36	05SPELT13	2000SPELT17 br	5475	67.0	110.0	123.7	5.3	79.7	44.8	60
40	05SPELT17	2000SPELT17 br	5493	67.0	109.8	123.5	4.5	81.0	41.5	50

Table 16. Quality evaluation of selected Spring Spelt wheat experimental lines grown at Saskatoon in 2005

ENTRY		Gpro	SDS	FN's	FY	Ash	HI	SKCS Agtron	L*	a*	b*
1	CDC Nexon	14.5	50	281	74.7	0.49	22.7	45.8	84.5	1.31	15.81
2	99SPELT9-Z	15.1	45	224	68.0	0.42	16.9	57.9	85.4	1.14	16.34
3	AC Barrie	15.0	60	428	73.8	0.49	60.8	65.3	86.3	1.25	15.13
8	04SPELT48	15.6	44	392	73.5	0.48	31.1	48.3	84.9	1.23	14.14
9	04SPELT49	15.2	44	384	73.4	0.46	27.3	48.1	84.6	1.31	14.41
17	04SPELT80	15.1	38	328	69.6	0.45	23.7	52.9	85.0	1.21	16.84
20	04SPELT88	14.9	35	343	69.9	0.44	23.1	56.2	85.4	1.10	16.74
23	04SPELT120	14.8	30	340	70.4	0.45	18.1	55.5	85.1	1.14	17.79
24	05SPELT1	15.5	52	282	70.4	0.42	26.0	58.0	85.5	1.15	16.18
28	05SPELT5	14.3	30	280	70.1	0.44	17.7	53.5	84.9	1.25	17.25
32	05SPELT9	15.0	35	362	69.6	0.46	24.4	57.8	85.4	1.12	17.55
33	05SPELT10	14.6	37	324	70.8	0.43	25.4	52.7	84.8	1.23	16.88
34	05SPELT11	14.4	33	353	71.4	0.42	21.8	56.6	85.3	1.12	17.80
36	05SPELT13	14.8	39	291	69.1	0.44	28.9	51.4	84.8	1.28	16.36
40	05SPELT17	15.1	35	368	69.2	0.43	21.0	57.3	85.4	1.11	16.97
		3*2reps	C	C	C	C	C	C	C	C	C

ENTRY	NAME	Peak Time	Peak Height	Total Energy	Band Width	Slope after peak	Energy peak	Fabs	DDT	MTI	CSP MT	LV	Loa shp
1	CDC Nexon	1.74	58.1	340.6	16.4	-3.62	77.8	58.8	1.7	60	4.9	885	3.0
2	99SPELT9-Z	1.59	51.7	287.6	36.0	-2.78	64.1	60.0	1.4	80	3.5	950	3.2
3	AC Barrie	2.39	60.6	364.5	22.6	-3.13	112.2	63.7	5.0	35	4.4	1010	4.0
8	04SPELT48	1.51	51.1	283.9	29.3	-1.98	61.6	61.1	1.3	75	2.4	925	3.3
9	04SPELT49	1.51	49.8	263.4	32.1	-1.75	59.9	61.1	1.3	85	3.6	875	2.5
17	04SPELT80	1.45	52.8	309.8	25.8	-3.7	60.2	62.8	1.1	70	2.6	880	2.2
20	04SPELT88	1.42	49.9	242.0	23.1	-3.5	56.0	62.0	1.2	95	3.0	910	2.6
23	04SPELT120	1.50	48.3	277.0	25.2	-4.21	58.0	59.1	1.3	80	2.2	890	2.7
24	05SPELT1	1.80	56.2	336.5	14.2	-4.11	78.3	58.8	2.2	60	4.2	975	3.7
28	05SPELT5	1.38	49.3	267.3	27.1	-3.42	54.0	60.2	0.8	105	2.4	865	2.9
32	05SPELT9	1.45	49.2	248.0	26.5	-2.53	56.6	60.0	1.5	70	2.6	920	3.0
33	05SPELT10	1.37	50.1	232.5	21.7	-2.77	54.2	62.8	0.7	95	2.8	940	3.2
34	05SPELT11	1.53	46.7	220.7	21.1	-2.79	57.7	60.4	1.2	75	2.4	890	2.8
36	05SPELT13	1.50	50.0	240.7	23.9	-2.5	59.0	62.0	1.0	75	3.1	890	2.9
40	05SPELT17	1.50	49.6	256.5	24.2	-3.92	59.0	60.8	1.1	100	2.4	915	3.0
		C	C	C	C	C	C	C	C	C	C	C	C

Table 17. Agronomic performance of Emmer-Durum derived lines evaluated in 2002 at three sites

Entry	ID	Grain yield (kg/ha)	DSE (d)	DPM (d)	Height (cm)	LBL (1-9)	Test wt kg/hL	Kernel wt mg	Grain Protein %	Yellow Pigment ppm	SDS-sed ml cc
1	EMMER19	2024	57.0	89.0	55.0	9.5	70.6	37.0	17.4	4.6	36.7
2	WB881	1545	53.0	95.8	47.8	7.5	74.9	48.8	17.2	7.5	42.0
3	KYLE	1874	56.5	98.5	60.5	3.5	75.7	43.7	18.3	7.0	30.2
4	00EB1	1696	54.8	87.3	41.8	8.5	71.9	42.7	17.9	5.3	51.7
5	00EB4	1660	52.0	88.3	57.8	9.5	74.3	44.9	17.9	5.8	57.2
6	00EB7	1539	55.5	91.0	53.8	9.0	71.4	42.0	17.2	6.2	51.7
7	00EB10	1723	56.0	91.5	49.5	8.5	74.0	41.9	17.2	5.6	48.2
8	00EB14	1430	55.5	99.0	51.3	7.0	73.7	44.7	16.9	6.6	57.3
9	00EB23	1153	54.3	90.0	48.8	9.0	71.2	41.9	18.9	5.5	51.7
10	00EB28	1585	54.0	91.8	50.3	9.5	71.5	42.6	16.4	5.0	57.3
11	00EB29	1463	55.0	95.3	48.3	7.0	73.5	41.2	16.8	4.9	55.5
12	02EB1	1683	53.3	90.3	48.5	9.5	75.2	45.2	15.3	6.1	61.7
13	02EB2	1618	53.3	93.0	50.0	9.5	75.0	43.5	16.6	5.5	51.2
14	02EB3	1729	52.8	91.0	48.0	10.0	75.3	41.7	15.5	5.6	53.3
15	02EB4	1870	53.8	89.5	49.5	9.0	72.6	40.5	15.4	6.6	57.5
16	02EB5	1744	54.5	95.0	42.0	9.5	74.7	43.3	16.0	7.2	49.7
17	02EB6	1844	53.8	93.3	44.3	9.5	73.7	48.1	16.7	5.9	49.8
18	02EB7	1790	52.5	89.5	42.5	9.0	74.3	43.4	15.7	5.8	52.0
19	02EB8	1866	55.0	95.5	50.0	8.5	74.6	42.2	16.0	7.3	45.8
20	Navigator	1954	55.0	99.0	50.5	8.0	76.5	49.1	16.8	8.6	37.8
	#of sites	3	2	2	2	1	3	3	3	3	3

Table 18. Agronomic performance of Emmer-Durum derived lines evaluated in 2003

ENTRY	NAME	Yield kg/ha	DSE days	DPM days	Height cm	Test wt kg/hL	Kwt mg
1	EMMER19	3641	57.3	86.7	64.8	77.2	40.2
2	WB881	2931	53.3	89.7	59.8	80.0	50.7
3	KYLE	3389	56.7	90.3	80.8	79.8	44.2
4	00EB1	2796	54.8	88.5	54.5	76.7	41.2
5	00EB4	2733	50.3	84.7	68.0	79.4	44.1
6	00EB7	2960	54.7	88.3	68.3	77.3	46.4
7	00EB14	3004	54.7	89.0	69.5	77.7	45.1
8	00EB23	2663	54.0	88.5	70.0	77.4	43.5
9	00EB28	2463	53.3	88.8	63.2	77.2	44.8
10	00EB29	2928	54.5	89.5	67.5	78.5	43.7
11	02EB1	2962	52.7	87.8	62.8	79.6	46.8
12	02EB4	2868	54.2	88.7	60.8	78.5	47.1
13	02EB8	2982	54.0	88.3	60.0	78.3	41.8
14	Navigator	3514	56.7	91.0	67.7	81.0	47.7
	# of sites	3	3	3	3	3	3

Table 19. Quality evaluation of selected emmer-durum derived experimental lines grown at Saskatoon in 2003

Entry	Grain Protein %	PSI %	Yellow pigment ppm	Flour yield %	Flour Protein %	Flour HunterLab L	Flour HunterLab a	Flour HunterLab b	Slurry HunterLab Refl540	Slurry HunterLab L	Slurry HunterLab a	Slurry HunterLab b
1 Emmer 19	17.2	46	4.47	69.7	15.3	82.26	1.42	12.24	67.08	79.85	1.60	12.89
2 WB 881	17.1	44	6.86	58.9	15.4	84.17	0.52	17.40	72.37	79.44	0.38	18.53
3 Kyle	17.7	46	5.61	55.0	15.7	84.60	0.57	16.53	72.76	80.66	0.29	17.43
4 00EB1	17.7	43	4.37	61.4	16.0	83.11	1.20	14.42	68.98	79.43	0.71	15.07
5 00EB4	17.7	45	5.41	64.0	15.9	83.93	0.67	15.58	71.36	78.92	0.55	16.64
6 00EB7	16.6	45	6.03	66.3	15.4	82.74	1.22	15.07	68.69	78.82	1.02	15.33
7 00EB10	16.9	44	4.99	64.0	15.1	83.59	1.13	15.25	70.07	80.14	0.78	15.99
8 00EB14	16.4	42	4.99	63.7	15.1	83.43	1.02	15.63	70.14	79.34	0.62	16.05
9 00EB23	18.3	46	4.06	63.1	16.7	82.73	1.22	13.00	68.17	78.62	1.52	14.32
10 00EB28	16.6	42	3.86	63.7	14.5	84.99	0.57	13.30	72.68	80.62	0.62	14.73
11 00EB29	16.8	45	3.86	60.2	14.7	84.20	0.95	12.76	70.77	79.55	0.63	13.56
12 02EB1	15.0	43	5.61	65.6	13.3	85.99	0.34	16.84	75.58	81.81	-0.10	18.08
15 02EB4	15.3	44	6.03	60.6	13.5	85.17	0.49	16.53	73.88	80.52	-0.21	16.92
17 02EB6	16.6	44	5.51	59.5	14.7	84.51	0.62	15.33	72.33	81.18	0.64	16.60
18 02EB7	15.6	44	4.78	56.8	13.7	85.02	0.44	15.27	73.28	80.47	-0.09	15.79
19 02EB8	15.6	47	6.13	65.9	14.1	85.58	0.45	17.19	74.82	82.39	0.24	18.72
20 Navigator	16.5	45	7.28	57.7	14.8	84.39	0.70	18.89	73.04	79.73	0.41	20.26
21 AC Barrie	17.3	58	3.12	74.9	15.8	87.76	0.71	10.15	76.88	83.67	0.76	12.23

Table 19 continued. Quality evaluation of selected emmer-durum derived experimental lines grown at Saskatoon in 2003

Entry	FAbs (%)	Farinograph DDT (min)	MTI	Stabilty (min)	CSP mixing time (min)	Loaf Volume (cc)	Crumb Structure		Crumb Color	
1 Emmer 19	66.6	2.5	75	2.8	2.0	990	2.0	coarse	2.0	grey
2 WB 881	70.3	2.5	95	2.8	4.2	915	2.0	coarse	1.0	yellow
3 Kyle	73.0	2.5	70	2.5	3.4	475	0.5	unacceptable	1.0	yellow
4 00EB1	72.0	5.0	45	6.1	5.8	1025	3.0		2.5	grey
5 00EB4	69.0	4.5	45	6.1	7.2	1015	3.0	sl.open	3.0	
6 00EB7	68.2	3.5	40	4.4	4.0	1000	3.5		2.5	grey
7 00EB10	67.8	2.5	60	4.0	5.0	840	2.5	open	3.0	
8 00EB14	68.8	4.0	50	5.7	6.0	995	3.5		3.0	
9 00EB23	70.3	4.5	45	5.7	5.5	1045	3.0		3.0	
10 00EB28	67.0	4.5	35	7.2	6.4	1005	3.0		3.5	
11 00EB29	67.0	5.5	35	8.0	5.2	940	2.5	coarse	3.0	
12 02EB1	64.9	4.5	45	7.4	7.4	910	3.0		2.0	light yellow,bright
15 02EB4	66.4	4.0	50	6.2	9.4	1015	3.0		2.0	light yellow,bright
18 02EB7	67.4	3.0	60	4.8	6.0	890	2.5		2.0	light yellow,bright
19 02EB8	66.3	3.0	60	3.2	3.6	950	3.0		2.0	light yellow,bright
20 Navigator	72.6	2.2	100	2.3	4.8	690	1.0		0.5	v.yellow, streaked
21 AC Barrie	66.3	5.5	10	16.3	6.5	1025	3.0	sl.open	3.5	

		Crust Color	Loaf Shape		Dough	
1 Emmer 9	ok	2.5	flat top	1.5	v.slack, sticky	
2 WB 881	speckled	2.0	flat top	3.0	sl.slack	
3 Kyle	pale,mottled	0.5	unacceptable	0.5	slack, no cohesion	(tore)
4 00EB1	ok	3.0		3.0	sl.slack	
5 00EB4	ok	4.0		4.0		
6 00EB7	ok	3.0	flat top	4.0		
7 00EB10	ok	3.0		4.0		
8 00EB14	ok	3.0	sl.flat top	3.5	sl.tight	
9 00EB23	ok	3.0		3.5	sl.tight	
10 EB28	ok	4.0		3.5	sl.tight	
11 0EB29	ok	2.5		3.5	sl.tight	
12 02EB1	ok	3.0		3.5	sl.tight	
15 02EB4	ok	2.5		3.5	sl.tight	
18 02EB7	speckled	2.5	flat top	2.5	slack, sticky	
19 02EB8	ok	3.0		2.0	slack, sticky	
20Navigator	speckled	1.0	flat split open top	2.5	slack	
21AC Barrie	pale	3.5		3.5		

Table 20. Agronomic performance of experimental Einkorn lines evaluated at three sites in 2002

Trt	ID	Grain Yield (kg/ha)	DSE (days)	DPM (days)	Height (cm)	LBL (1 - 9)	Grain Protein (%)	Yellow Pigment (ppm)	SDS Sed (ml)	Test Weight (kh/hL)	Kernel Weight (mg)	Threshability (%)
1	AC Barrie	2354	50.8	92.8	54.8	7.0	16.9	4.96	59.5	76.4	32.4	96.0
2	TM23	2235	53.3	98.8	62.0	1.5	18.7	6.90	10.5	76.1	31.2	37.0
3	Uno	1484	52.0	99.0	61.8	2.0	19.0	10.95	10.7	73.2	32.4	81.8
4	98EINK31	1582	52.3	97.8	68.5	2.0	18.1	8.59	9.3	75.6	30.6	70.4
5	2000EINK1	2603	53.8	100.8	67.0	0.0	18.0	8.66	9.7	78.1	30.7	35.3
6	2000EINK3	2147	53.8	101.5	64.8	0.5	17.3	8.56	9.8	77.8	30.5	33.4
7	2000EINK11	2504	53.3	95.0	64.8	4.0	19.7	7.24	9.8	77.9	29.6	29.9
8	2000EINK22	2381	53.3	98.3	66.8	1.0	18.0	8.21	9.0	77.4	32.0	30.0
9	2002EINK1	1755	52.5	100.3	65.8	1.0	18.4	9.70	9.7	76.5	28.3	87.6
10	2002EINK2	1776	53.0	99.8	65.8	2.0	18.4	9.70	9.5	76.5	28.6	87.0
11	2002EINK3	1723	51.0	93.8	64.8	4.0	18.3	7.52	9.8	74.8	31.7	86.5
12	2002EINK4	1804	52.0	97.5	67.8	4.0	18.2	7.90	9.8	75.1	32.3	85.9
13	2002EINK5	1740	52.5	99.3	63.8	1.0	18.3	10.22	10.2	76.8	28.7	87.4
14	2002EINK6	1387	51.3	94.5	67.8	4.0						
15	2002EINK7	1426	51.3	92.5	63.0	5.0						
	# of sites	3	2	2	2	1	3	3	3	3	3	3

Table 21. Quality evaluation of selected Einkorn experimental lines grown at Saskatoon in 2002

	ID	Grain Protein (%)	Flour Yield (%)	Flour Protein (%)	Flour Ash (%)	Flour color Hunter-Lab L	a	b	L540	H-L Flour slurry L	a	b
1	AC Barrie	16.7	73.1	15.7	0.61	88.9	0.52	10.5	78.9	82.7	0.11	12.4
2	TM23	18.2	64.8	16.9	0.59	90.9	0.13	11.4	83.6	77.7	0.38	20.5
3	Uno	18.7	65.3	17.4	0.77	89.8	0.28	13.2	81.8	76.6	1.29	22.8
5	2000 EINK 1	17.5	64.2	16.3	0.59	90.6	0.12	13.5	83.5	77.5	0.47	23.7
8	2000EINK22	17.2	66.3	16.1	0.59	90.8	0.01	13.1	83.8	78.2	0.53	23.4
10	2002EINK2	17.7	64.2	16.9	0.65	90.3	0.05	14.7	83.3	76.6	0.70	26.3
12	2002EINK4	17.7	66.5	16.4	0.59	90.4	0.13	13.1	83.1	76.9	0.87	23.4
13	2002EINK5	17.9	63.8	16.6	0.67	90.2	0.07	14.8	83.1	76.7	0.90	26.1

TRT	NAME	Fabs (%)	DDT (min)	MTI (BU)	Stab (min)	MT (min)	Loaf vol (cc)	Crumb color	taste	taste
1	AC Barrie	68.40	8.0	15	25.5	5.5	1070	creamy	sweet	
2	TM23	63.20	0.4	220	0.5	0.3	570	light yellow	sweet	bit nutty
3	Uno	62.60	0.6	220	0.5	0.6	500	yellow		strong nutty
5	2000 EINK 1	62.00	0.4	280	0.4	0.5	520	light yellow	sweet	bit nutty
8	2000EINK22	62.40	0.5	260	0.5	0.4	545	light yellow	sweet	bit nutty
10	2002EINK2	61.40	0.5	260	0.4	0.8	500	yellow	sweet	bit nutty
12	2002EINK4	63.60	0.7	250	0.5	0.5	560	yellow		
13	2002EINK5	61.40	0.5	255	0.5	0.3	550	very yellow	sweet	bit nutty

Table 22. Agronomic performance of selected Einkorn lines evaluated at either four sites (22a) or three sites (22b) in 2003.

ENTRY	Table 22a	Grain yield (kg/ha)	%TM23	DSE (days)	(DPM days)	Height (cm)	Lodged (1 to 9)	Test Weight (kg/hL)	Kernel Weight (mg)	Threshability (%)	Protein (%)	SDS sed (ml)	Yellow Pigment (ppm)
1	AC Barrie	3700	108.2	53.9	85.3	73.4	1.5	80.9	34.1	99	16.9	57	2.9
2	TM23	3419	100.0	55.9	86.8	80.3	5.5	78.4	30.3	31	18.2	11	4.6
3	Uno	1899	55.5	56.3	87.8	80.1	2.0	76.4	35.4	91	20.3	10	8.9
4	2000EINK1	3354	98.1	56.3	86.8	79.6	5.5	79.4	29.6	46	17.7	10	5.1
5	2000EINK22	3465	101.3	55.5	85.5	79.0	8.0	78.9	30.5	37	18.1	10	5.0
6	2002EINK2	2358	69.0	56.5	88.0	82.8	2.5	78.4	30.4	95	19.5	10	5.9
8	2002EINK5	2381	69.6	56.4	86.8	82.1	2.5	78.4	30.0	93	19.2	10	6.2
12	2003EINK3	2415	70.6	56.5	87.7	80.8	1.5	78.3	34.3	91	19.5	9	4.9
16	2003EINK7	2346	68.6	57.1	88.3	81.0	2.5	77.7	27.8	95	19.3	9	6.9
19	2003EINK10	2503	73.2	55.9	86.3	84.5	2.5	76.5	30.6	89	19.1	10	6.1
	# of sites	4		4	3	4	2	2	2	4	4	4	4

ENTRY	Table 22b	Grain Yield (kg/ha)	%TM23	DSE (days)	DPM (days)	Height (cm)	Lodged (1 to 9)	Threshability (%)	Protein (%)	SDS Sed (ml)	Yellow Pigment (ppm)
1	AC BARRIE	4362	**118.2**	51.8	85.5	79.7	1.5	95	15.8	58.5	2.8
2	TM23	3690	**100.0**	55.0	87.5	81.8	5.3	41	17.9	10.9	4.7
3	UNO	2346	**63.6**	54.0	87.3	82.5	2.3	72	20.0	10.4	7.7
4	2003EINK17	3469	**94.0**	60.7	90.2	99.3	2.0	39	18.7	12.6	8.8
5	2003EINK18	3411	**92.4**	58.5	88.8	97.3	4.8	47	18.1	23.9	10.0
6	2003EINK19	3724	**100.9**	59.5	91.0	100.0	4.0	46	18.0	21.0	9.2
7	2003EINK20	3401	**92.2**	59.8	90.3	94.0	3.8	48	17.4	20.9	10.6
9	2003EINK22	3244	**87.9**	61.0	91.5	98.3	6.0	32	19.1	29.3	8.9
10	2003EINK23	3938	**106.7**	57.7	88.5	96.7	4.5	41	17.0	13.0	8.8
11	2003EINK24	3419	**92.7**	60.3	91.0	104.5	5.3	27	19.2	13.8	9.7
13	2003EINK26	3508	**95.1**	59.5	89.5	96.7	5.8	43	18.1	28.8	7.3
16	2003EINK29	3976	**107.7**	60.0	88.8	101.0	2.8	21	18.8	12.2	9.0
17	2003EINK30	3619	**98.1**	54.2	88.2	97.2	3.8	33	19.4	11.2	8.8
20	2003EINK33	3555	**96.4**	58.2	89.2	100.0	4.3	47	17.7	30.3	7.7
21	2003EINK34	3514	**95.2**	59.7	90.0	101.0	4.0	41	17.7	28.6	7.6
22	2003EINK35	3890	**105.4**	59.8	89.7	97.0	3.0	14	19.9	38.0	8.0
24	2003EINK37	3566	**96.6**	59.8	90.0	96.5	5.3	44	17.9	28.3	7.5
29	2003EINK42	3304	**89.6**	58.0	88.0	96.0	3.8	26	19.5	36.7	5.9
31	2003EINK44	3794	**102.8**	60.0	89.7	100.5	3.0	24	19.3	12.5	9.3
	# of sites	3	3	3	3	3	2	2	3		

Table 23. Agronomic performance of selected experimental Einkorn lines evaluated at four sites in 2004

	NAME		Grain yield (kg/ha)	%TM23	DSE (days)	DPM (days)	Height (cm)	Lodged (1to9)	Plant Stand (1to9)	Thresh. (%)
1	AC Barrie		4715	**103.2**	62.1	107.2	93.4	2.0	9.0	99
2	TM23		4568	**100.0**	65.1	114.2	95.6	5.0	8.8	17
3	Uno		3189	**69.8**	64.1	114.5	95.1	3.0	8.5	77
4	2000 EINK 1		4317	**94.5**	64.8	116.2	94.1	4.2	8.5	18
5	2000EINK22		4220	**92.4**	63.6	111.3	93.1	5.8	9.0	16
6	2002EINK2		2657	**58.2**	64.9	118.7	96.8	1.7	7.0	cull
7	2002EINK5		2701	**59.1**	64.6	117.7	96.1	2.0	7.3	cull
9	2003EINK3	98EINK9/TM23	2873	**62.9**	64.9	116.5	95.5	2.0	7.8	cull
10	2003EINK7	98EINK9/TM23	2653	**58.1**	65.4	120.5	95.3	1.8	7.0	cull
11	2003EINK10	98EINK9/TM23	3264	**71.5**	63.9	113.0	99.5	2.5	8.5	68
12	2003EINK17	TM11073	3542	**77.5**	70.0	125.8	105.1	3.2	8.0	22
13	2003EINK18	TM20450	3026	**66.2**	68.4	122.5	105.1	3.3	8.0	38
14	2003EINK20	TM43450	2920	**63.9**	68.9	125.5	101.6	2.7	7.0	39
15	2003EINK23	TM43483	3701	**81.0**	67.3	123.8	110.6	3.7	7.8	22
16	2003EINK24	TM43485	3675	**80.5**	69.6	122.5	113.0	4.2	8.3	24
17	2003EINK33	TM3520	3310	**72.4**	68.3	123.2	107.9	3.5	7.3	27
18	2003EINK35	TM13192	3839	**84.0**	69.4	126.2	101.9	3.0	7.8	19
19	2003EINK37	TM42007	3931	**86.1**	67.6	117.7	106.9	3.3	9.0	19
20	2003EINK41	TM43449	3850	**84.3**	68.6	118.7	112.0	2.2	8.5	17
21	2003EINK42	TM43477	3651	**79.9**	67.5	115.7	105.5	4.0	8.5	16
22	2003EINK44	TM43500	4123	**90.2**	68.8	121.2	107.3	2.2	5.5	16
		# of sites	4		4	3	4	3	2	4

Table 24. Quality evaluation of selected Einkorn experimental lines grown at Saskatoon in 2004

ENTRY	NAME		Grain Protein (%)	SDS Sed (ml)	Yellow Pigment (ppm)	SKCS (HI)	Falling Number (sec)	Mixograph Peak Time	Mixograph Peak Height	Mixograph Total Energy	Mixograph Band Width	Mixograph Slope after Peak	Mixograph Energy to Peak	PPO 10 seeds/rep Abs. at 475 nm
1	AC Barrie	**2004 EINKYT**	14.8	66.5	3.2	56.9	504	2.33	64.7	391.3	27.7	-3.49	117.8	0.403
2	TM23		16.1	7.8	6.1	8.4	524	1.25	32.4	178.5	19.0	-1.50	32.2	0.917
3	Uno		17.0	8.0	9.1	6.3	549	1.08	34.2	169.8	16.4	-2.43	29.3	1.237
4	2000 EINK 1		16.1	7.6	7.3	7.4	689	1.03	30.8	156.2	14.5	-2.39	25.0	0.707
5	2000EINK22		16.5	7.8	6.9	8.2	613	1.16	32.5	145.0	12.4	-3.00	30.7	1.062
11	2003EINK10	98EINK9/TM23	16.6	7.6	7.4	8.0	661	1.08	33.8	164.9	16.6	-2.45	28.6	0.937
12	2003EINK17	TM11073	16.5	9.3	10.9	14.9	632	1.13	36.3	131.3	4.3	-2.86	32.4	0.489
13	2003EINK18	TM20450	15.8	27.4	13.3	21.6	674	1.35	41.7	231.4	23.0	-3.72	43.7	0.573
14	2003EINK20	TM43450	15.3	20.5	13.7	19.6	639	1.20	38.9	216.5	26.1	-3.40	36.8	0.467
15	2003EINK23	TM43483	15.1	8.6	11.0	18.6	555	1.11	34.6	163.4	15.7	-2.74	30.3	0.596
16	2003EINK24	TM43485	16.7	7.9	11.9	17.5	733	1.11	34.7	179.4	21.6	-2.06	30.3	0.609
17	2003EINK33	TM3520	15.6	26.3	10.9	17.1	588	1.44	39.2	226.5	20.9	-2.42	44.5	0.562
18	2003EINK35	TM13192	18.6	27.5	10.4	11.0	604	1.29	49.0	291.4	24.8	-3.29	49.1	0.494
19	2003EINK37	TM42007	15.3	19.3	10.3	19.3	591	1.33	38.3	213.5	21.1	-2.22	39.5	0.562
20	2003EINK41	TM43449	17.0	10.0	10.5	13.2	542	1.27	36.3	165.1	13.4	-3.20	35.4	0.456
21	2003EINK42	TM43477	16.8	23.5	8.3	9.1	740	1.16	42.4	192.1	19.4	-3.31	38.2	0.672
22	2003EINK44	TM43500	17.2	7.8	11.0	14.9	571	0.97	32.0	155.2	15.4	-2.06	24.4	0.588
		# of sites	4	4	4	4	C	C	C	C	C	C	C	3 reps

Table 25. Advanced quality evaluation of selected Einkorn experimental lines grown at four sites near Saskatoon in 2003

Sample		Flour yield (%)	Flour Ash (%)	Flour Protein (%)	H-L slurry L	a	b	Ferulic acid mg/100g
1	AC Barrie	75.4	0.40	15.0	84.54	0.10	12.34	63.5
2	TM23	70.3	0.45	15.9	80.57	0.43	20.01	60.4
3	Uno	69.8	0.58	18.1	80.07	0.82	21.75	48.7
4	2000EINK1	71.2	0.43	16.2	80.90	0.27	22.45	61.6
5	2000EINK22	69.1	0.45	16.4	82.13	0.37	23.16	59.2
6	2002EINK2	68.6	0.50	17.4	79.36	0.33	24.93	52.7
12	2003EINK3	70.2	0.49	17.5	79.89	0.20	21.67	50.7
16	2003EINK7	68.8	0.51	17.3	78.94	0.58	25.20	53.7
19	2003EINK10	68.5	0.54	16.8	81.10	0.79	23.29	64.9

Sample	Volume Index	Contour Index	Uniformity Index	Volume LxWxHt	Crumb Structure	Crumb Color	Appearance top color	Cake symmetry	Flavor
1a	9.0	0.4	0.1	218	coarse	creamy	light, sl.uneven	good	normal, sweet
1b	9.5	0.6	0.3	223	coarse	creamy	light, sl.uneven	good	normal, sweet
2	10.1	0.9	0.3	241	fine	pale yellow	yellow, uneven	good	sweet, a bit nutty
3	9.7	0.7	0.2	231	fine	yellow	yellow, uneven	good	sweet, a bit nutty
4	10.2	0.8	0.3	236	fine	yellow	yellow, uneven	good	sweet, a bit nutty
5	10.2	1.0	0.2	230	fine	yellow	yellow, uneven	good	sweet, a bit nutty
6	10.2	1.0	0.2	244	fine	yellow	yellow, uneven	fair	sweet, a bit nutty
12	9.7	0.5	0.1	233	sl.coarse	pale yellow	yellow, uneven	good	sweet, a bit nutty
16	9.8	1.0	0.1	240	fine	yellow	yellow, uneven	good	sweet, a bit nutty
19	10.0	0.7	0.2	225	fine	yellow	darker, uneven	good	sweet, a bit nutty
Ctrl A	10.6	0.7	0.3	218	v.fine	bright white	golden, smooth	excellent	sweet, normal, dry, flavorless
Ctrl B	10.7	0.9	0.1	207	v.fine	bright white	golden, smooth	excellent	sweet, normal, dry, flavorless
LSD	1.2	0.8	ns	34					

Baking was done in the CSP bread baking pans, 7 on each bake day

Contour (Symmetry) Index: 0 = flat, as values increase >0, the cake was higher in the middle (some quite "peaked")

Uniformity Index: 0 = uniformly rounded, as values increase >0, the cake becomes more lopsided

Table 25 continued. Advanced quality evaluation of selected Einkorn accessions grown at three sites near Saskatoon in 2003

Trt	ID	Flour yield %	Flour Ash %	Flour protein %	H-L slurry L*	a*	b*	Fabs %	DDT min	MTI BU	BW5 BU
1	AC Barrie	75.2	0.37	14.4	83.5	0.05	12.37	62.2	6.5	18	70
2	TM23	70.5	0.45	15.8	81.2	0.43	20.13	59.4	0.7	220	10
3	Uno	70.4	0.54	17.7	78.4	0.78	21.87	59.6	0.5	220	15
5	2003EINK18	70.5	0.45	16.9	80.9	1.28	23.75	59.4	1.8	115	25
6	2003EINK19	70.1	0.44	16.0	80.3	0.97	22.41	58.4	1.3	105	25
7	2003EINK20	69.0	0.45	16.1	81.5	1.04	23.88	58.3	1.4	120	30
9	2003EINK22	69.0	0.51	17.3	80.8	0.95	21.92	60.6	1.3	95	45
13	2003EINK26	66.8	0.47	16.2	81.8	0.97	21.20	59.6	1.4	90	40
20	2003EINK33	68.4	0.43	16.1	80.7	0.86	20.96	59.6	1.2	95	40
21	2003EINK34	67.0	0.47	15.7	81.7	0.99	21.30	60.0	1.1	105	45
22	2003EINK35	69.3	0.52	17.9	83.0	0.90	20.39	61.4	0.9	65	60
24	2003EINK37	68.4	0.46	16.0	80.8	0.93	20.99	59.9	1.2	90	45
29	2003EINK42	70.3	0.48	18.1	82.6	0.73	21.63	60.6	1.4	90	45

		MxTm min	LV cc	Crust col.	Loaf shape	Crumb struct	Crumb color	Dough handle	Ferulic acid
1	AC Barrie	6.0	1050	4.0	4.0	3.5	3.5	4.0	60.2
2	TM23	0.6	635	0.5	0.5	0.5	0.5	0.5	59.7
3	UNO	0.6	500	0.0	0.0	0.5	0.5	0.5	46.0
5	2003EINK18	1.2	915	3.5	2.5	1.8	1.0	2.0	54.5
6	2003EINK19	1.4	850	2.5	2.5	1.8	1.0	1.5	54.9
7	2003EINK20	1.5	815	2.5	2.0	2.0	0.5	1.5	60.5
9	2003EINK22	1.5	815	2.5	1.5	0.8	0.5	2.0	51.1
13	2003EINK26	2.0	905	3.5	2.5	2.8	1.5	2.0	48.2
20	2003EINK33	1.5	985	3.5	3.3	2.5	1.8	2.0	47.6
21	2003EINK34	1.3	940	3.0	3.0	2.8	1.5	2.0	59.2
22	2003EINK35	1.3	945	3.5	3.0	2.5	1.5	2.0	69.6
24	2003EINK37	2.1	940	3.5	3.0	3.0	1.5	1.5	59.7
29	2003EINK42	1.1	940	3.5	2.5	2.0	1.0	2.0	57.6

Table 26. Agronomic performance of selected Einkorn lines grown at four sites in 2005

ENTRY	NAME		Grain Yield (kg/ha)	%TM23	DSE (days)	DPM (days)	Height (cm)	Lodged (1to9)	LBL (1to9)
1	AC Barrie		4034.5	**97.1**	57.8	100.0	97.9	2.3	4
2	TM23		4157.0	**100.0**	60.5	103.1	100.5	4.3	1
3	UNO		2436.9	**58.6**	59.6	105.1	96.8	2.5	1
4	2000 EINK 1		4032.3	**97.0**	60.0	103.9	100.8	3.5	1
5	2000EINK22		4191.8	**100.8**	59.0	98.9	99.1	5.0	1
6	2003EINK10	98EINK9/TM23	2785.8	**67.0**	59.8	104.8	103.0	2.3	1
7	2003EINK17	TM11073	3879.8	**93.3**	64.9	112.3	94.0	3.0	1
8	2003EINK18	TM20450	3323.6	**80.0**	62.5	109.9	107.8	3.8	1
9	2003EINK20	TM43450	3586.6	**86.3**	63.5	110.3	105.1	3.0	1
10	2003EINK23	TM43483	3963.4	**95.3**	62.6	110.0	111.9	4.5	1
11	2003EINK24	TM43485	3920.3	**94.3**	64.3	109.8	112.4	4.3	1
12	2003EINK33	TM3520	3807.8	**91.6**	63.1	109.9	109.3	4.0	2
13	2003EINK35	TM13192	4194.0	**100.9**	64.0	109.4	103.5	3.0	2
14	2003EINK37	TM42007	4034.6	**97.1**	63.1	110.1	107.1	3.8	1
15	2003EINK41	TM43449	3717.0	**89.4**	63.8	108.5	110.9	3.3	5
16	2003EINK42	TM43477	3775.8	**90.8**	62.4	105.3	107.5	3.3	1
17	2003EINK44	TM43500	4290.1	**103.2**	64.0	110.1	105.3	3.3	1
25	2005EINK8	Einkorn9/TM23	2705.3	**65.1**	60.5	107.9	92.8	1.8	1
		# of sites	4		4	4	4	4	1

Table 27. Quality evaluation of selected Einkorn lines grown in 2005

TRY	NAME		Grain Protein (%)	SDS Sed (ml)	FN (sec)	SKCS HI	Yellow Pig (ppm)	PPO Abs450	Chloro-phyll	H-L grain color a*	H-L grain color b*	Peak Time	Peak Height	Total Energy	Band Width	Energy to peak	Loaf Vol (cc)
1	AC Barrie		14.8	59.8	411	59	3.0	0.364	0.00	6.63	12.99	2.16	64.4	391.5	29.2	107.7	1065
2	TM23		17.0	9.5	402	8	5.1	0.783	0.33	7.25	14.61	1.19	33.8	137.8	16.7	32.1	495
3	UNO		18.0	9.5	354	1	8.5	0.858	0.07	5.86	13.22	1.06	35.2	153.4	13.4	29.8	500
4	2000 EINK 1		16.7	8.5	458	5	6.1	0.667	0.46	7.22	14.68	1.02	33.1	144.9	22.0	26.9	*
5	2000EINK22		16.4	8.5	417	7	6.0	0.819	0.07	7.28	14.47	1.15	33.3	137.2	14.9	30.8	*
6	2003EINK10	98EINK9/TM23	17.6	9.0	469	8	6.5	0.635	0.19	6.76	13.89	1.08	36.4	133.3	11.2	31.8	*
7	2003EINK17	TM11073	17.4	11.3	462	8	9.4	0.819	1.40	6.07	14.13	1.15	39.4	163.5	14.5	36.2	*
8	2003EINK18	TM20450	16.9	31.5	536	14	10.9	0.869	1.08	7.35	14.18	1.19	45.2	214.3	20.6	42.0	845
9	2003EINK20	TM43450	15.7	25.3	540	15	11.5	0.659	1.04	6.96	14.25	1.20	40.8	171.2	12.1	38.2	820
10	2003EINK23	TM43483	15.8	10.3	425	13	9.8	0.585	1.24	5.91	13.03	1.10	36.7	137.1	10.0	32.0	*
11	2003EINK24	TM43485	16.7	8.3	505	11	10.8	0.845	1.46	7.20	14.70	0.94	34.9	103.2	7.6	26.0	*
12	2003EINK33	TM3520	16.0	31.0	476	14	9.1	0.506	1.04	6.46	13.54	1.32	41.9	193.1	17.4	43.7	855
13	2003EINK35	TM13192	18.6	30.3	509	1	8.1	0.650	1.08	7.05	14.74	1.30	49.3	243.5	17.1	50.7	885
14	2003EINK37	TM42007	15.9	27.5	492	16	9.0	0.571	0.62	5.53	12.94	1.27	42.7	192.6	18.6	41.9	735
15	2003EINK41	TM43449	17.7	11.3	469	8	9.5	0.556	0.85	6.91	14.67	1.11	40.5	159.4	13.4	36.2	*
16	2003EINK42	TM43477	17.8	31.5	525	3	7.0	0.808	0.62	6.64	14.07	1.13	46.8	208.7	19.8	41.9	*
17	2003EINK44	TM43500	16.9	7.8	488	9	10.0	0.837	0.78	7.03	14.75	0.98	33.6	136.2	14.5	26.4	910
25	2005EINK8	Einkorn9/TM23	17.1	9.3	460	8	6.9	0.735	1.01	6.66	14.10	1.14	32.9	217.1	12.6	30.2	*
		# of sites	4	4	C	4	4	C	C	4	4	C	C	C	C	C	C

Table 27 continued. Quality evaluation of selected Einkorn lines grown in 2005, milling characteristics

ENTRY	NAME		Flour yield	Hunterlab (Flour samples)				Hunterlab (flour slurry method)		
			%	L*	a*	b*	Agtron	L*	a*	b*
1	AC Barrie		75.1	86.66	0.96	11.30	**55.6**	85.43	1.38	14.90
2	TM23		64.1	89.51	0.24	11.69	**15.9**	80.39	1.91	26.00
3	Uno		63.7	88.22	0.40	12.79	**-10.1**	77.08	2.49	28.21
4	2000 EINK 1		68.8	89.12	0.31	13.58	**16.6**	80.11	2.05	29.74
5	2000EINK22		64.2	89.50	0.13	13.45	**16.8**	80.05	2.01	30.60
6	2003EINK10	98EINK9/TM23	65.3	89.02	0.30	13.85	**14.3**	79.57	2.25	30.46
7	2003EINK17	TM11073	60.8	89.35	0.19	13.68	**32.2**	81.66	1.51	27.96
8	2003EINK18	TM20450	66.1	88.02	0.55	15.25	**26.0**	81.30	2.22	30.02
9	2003EINK20	TM43450	63.4	88.26	0.49	15.54	**32.2**	81.74	2.02	29.69
10	2003EINK23	TM43483	61.2	88.66	0.29	14.54	**27.0**	81.24	1.65	29.58
11	2003EINK24	TM43485	59.6	89.33	0.30	14.37	**31.3**	81.56	1.71	29.48
12	2003EINK33	TM3520	63.8	88.60	0.34	13.71	**33.1**	82.14	1.65	26.82
13	2003EINK35	TM13192	64.3	89.40	0.36	13.03	**39.7**	82.94	1.79	25.15
14	2003EINK37	TM42007	61.2	88.50	0.27	13.37	**27.6**	81.61	1.46	26.67
15	2003EINK41	TM43449	63.9	89.32	0.38	13.98	**17.5**	80.19	2.26	30.62
16	2003EINK42	TM43477	65.0	89.33	0.26	13.45	**31.4**	81.92	1.82	28.12
17	2003EINK44	TM43500	61.6	89.23	0.33	14.70	**19.2**	80.10	2.10	32.24
19	2005EINK2	Einkorn9/TM23	70.6	89.06	0.31	12.98	**15.5**	80.32	2.19	28.09
			C	C	C	C	C	C	C	C

Table 28. Agronomic performance of large seeded Khorasan type wheat lines in 2002

ENTRY		Yield (kg/ha)	DSE (days)	DPM (days)	Height (cm)	LBL (1-9)	Test weight (kg/hL)	Kernel weight (mg)
1	AC Avonlea	2332	51.7	96.8	57.3	3.0	77.9	48.9
2	PI211691	2193	52.7	94.3	73.5	2.0	74.0	60.7
3	99PUFF1	2284	51.7	98.3	57.3	6.0	71.9	53.2
5	02PUFF2	2130	52.8	102.2	56.3	3.0	71.0	55.9
6	02PUFF3	2166	50.3	97.7	55.7	3.5	74.9	59.9
9	02PUFF6	2167	52.7	97.3	69.2	5.0	75.3	59.8
14	02PUFF11	2251	51.3	101.5	58.3	5.0	71.0	53.5
15	02PUFF12	2302	51.5	96.8	63.2	9.0	75.2	54.4
16	02PUFF13	2385	53.0	98.5	53.3	4.5	73.6	62.4
17	02PUFF14	2663	52.7	97.5	71.2	6.0	75.9	58.1
18	02PUFF15	2635	54.0	100.8	56.8	6.0	71.9	54.0
19	***02PUFF16***	2190	52.7	97.3	60.3	6.5	74.7	57.6
22	02PUFF19	2274	51.2	97.3	56.3	6.5	71.3	57.7
23	02PUFF20	2447	53.3	101.2	61.2	4.0	71.1	59.4
24	02PUFF21	2497	53.7	100.5	66.5	7.0	73.1	63.0
	# of sites =	4	3	3	3	1	2	2

Table 29. Agronomic performance of selected Khorasan type wheat lines in 2003.

ENTRY	NAME	Yield (kg/ha)	DSE (days)	DPM (days)	Height (cm)	Test wt (kg/hL)	Kwt (mg)	20SL (cm)	spike morf
1	AC Avonlea	4183	51.5	86.7	78.2	80.5	48.0	14.0	
2	PI211691	3677	54.8	86.8	94.3	77.8	68.1	18.0	
3	99PUFF1	3684	53.2	89.0	68.2	78.4	66.2	16.5	
4	02PUFF3	3590	51.7	88.8	69.2	80.0	69.7	17.3	
5	02PUFF6	3457	52.3	88.7	82.8	78.8	65.6	17.8	
6	02PUFF13	3709	54.0	89.7	65.2	76.9	62.2	16.5	
7	***02PUFF16***	3420	53.7	88.5	70.7	78.5	70.3	18.3	pol
8	02PUFF21	3933	54.2	89.0	77.2	77.4	68.8	18.0	
9	03PUFF1	3788	53.8	87.5	66.2	78.6	64.1	17.5	
10	03PUFF2	3805	54.3	89.2	71.0	76.6	60.7	19.3	
11	03PUFF3	4037	55.2	89.8	68.5	78.8	60.0	17.5	
12	03PUFF4	3832	54.2	89.2	66.3	77.3	65.4	18.0	
13	03PUFF5	3852	55.2	90.2	68.2	77.6	62.0	17.8	
16	03PUFF8	3827	54.5	89.3	66.5	78.5	70.3	18.8	
17	03PUFF9	3964	54.3	89.0	72.0	77.8	57.3	18.0	
18	***03PUFF10***	3514	53.5	89.5	67.3	78.3	60.2	17.8	pol
19	03PUFF11	4008	53.7	90.3	70.3	79.5	64.7	17.5	
		3	3	3	3	2	2	2	

Spike morf = spike morphology; pol = polonicum type.

Table 30. Agronomic performance of selected Khorasan-type wheat lines in 2004.

ENTRY	NAME	Yield (kg/ha)	%Avn	DSE (days)	DPM (days)	Height (cm)	Lodged (1to9)	LBL (1to9)
1	AC Avonlea	5183	**100.0**	61.4	120.0	93.9	1.2	2.5
2	PI211691	4453	**85.9**	63.4	*	113.1	4.2	3.5
3	99PUFF1	4315	**83.3**	62.1	121.2	73.1	1.5	5.5
4	02PUFF3	4483	**86.5**	62.1	122.3	74.3	1.3	4.0
5	02PUFF6	4438	**85.6**	62.9	115.0	104.0	2.8	4.5
6	***02PUFF16***	4161	**80.3**	63.1	120.2	74.4	1.5	3.5
7	02PUFF21	4802	**92.7**	65.1	124.3	84.1	1.5	4.5
8	03PUFF2	4624	**89.2**	64.0	122.2	74.5	1.3	2.5
9	03PUFF4	4673	**90.2**	64.0	122.8	72.4	1.2	2.0
10	03PUFF8	4273	**82.4**	63.4	122.5	67.8	1.3	5.0
11	03PUFF11	5072	**97.8**	63.3	123.0	75.9	1.3	2.5
	#of sites	4		4	3	4	3	1

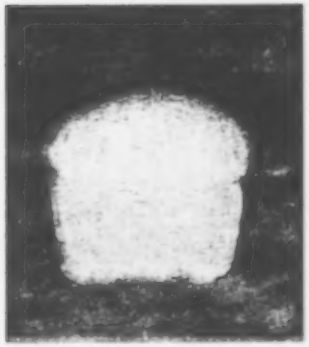
Table 31. Agronomic performance of selected Khorasan-type wheat lines grown at three sites in 2005.

Trt			Grain Yield (kg/ha)	DSE (days)	DPM (days)	Height (cm)	Test Weight (kg/hL)	Kernel Weight (mg)	20SL (cm)	Lodged (1to9)	LBL (1to9)	Grain Protein (%)	SDS Sed (ml)	YPig (ppm)
1	AC Avonlea		5170	62.0	113.0	94.0	79.8	43.1	14.9	1.5	4	15.1	28	6.3
2	PI211691		4846	63.8	109.5	116.2	77.8	65.6	19.4	5.0	4	13.7	20	5.5
3	99PUFF1		3852	61.7	112.7	67.8	75.2	56.7	18.0	1.5	6	14.1	34	5.4
5	***02PUFF16***		3924	61.8	111.7	73.3	75.8	51.3	17.7	2.0	4	13.3	22	3.4
6	02PUFF21		4881	63.8	113.8	80.2	76.2	61.9	17.8	2.0	5	12.8	29	7.2
7	03PUFF2	XPUF97.8	4554	63.0	114.2	71.2	73.8	54.9	19.1	2.0	4	12.2	33	5.6
8	03PUFF4	XPUF97.171	4511	63.5	116.3	70.8	74.7	57.8	18.5	1.0	3	13.1	30	6.1
10	03PUFF11	X99PUFF2	4702	62.3	115.3	68.5	76.7	56.5	17.3	1.0	4	13.9	26	4.9
11	05PUFF1	PI211691/DT661	4987	62.5	112.5	105.2	78.4	60.9	17.4	1.5	5	14.0	22	5.5
17	***05PUFF7***	***X96.160/K2973-80B***	4074	61.7	115.3	72.8	73.7	58.3	19.9	1.5	4	13.8	34	5.5
18	05PUFF8	99PUFF1/99PUFF4	4519	62.5	112.0	77.8	75.8	62.4	18.1	2.0	4	13.2	27	5.4
24	05PUFF14	99PUFF1/99PUFF4	4909	61.5	110.3	79.7	77.6	56.9	17.3	2.0	5	12.8	31	4.8
26	05PUFF16	99PUFF1/99PUFF4	4555	62.7	113.2	79.8	78.2	63.5	17.9	1.5	6	13.0	27	4.0
28	05PUFF18	99PUFF1/99PUFF4	4713	62.2	111.0	78.0	76.9	58.0	17.2	2.0	6	13.0	30	5.9
		# of sites	3	3	3	3	3	3	3	2	1	3	3	3

AC Barrie
970cc

TM23
465cc

UNO
465cc



Entry #8
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Entry #13
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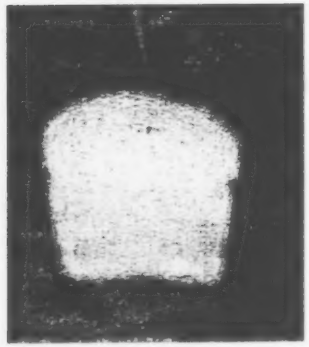

Entry #16
835cc